THE ECONOMY OF THE EYES.—PART II.

OF

# TELESCOPES;

BEING

THE RESULT OF THIRTY YEARS' EXPERIMENTS

WITH

FIFTY-ONE TELESCOPES,

OF FROM ONE TO NINE INCHES IN DIAMETER,

IN THE POSSESSION OF

WILLIAM KITCHINER, M.D.

AUTHOR OF

THE COOK'S ORACLE;
THE HOUSEKEEPER'S LEDGER;
THE ART OF INVIGORATING AND PROLONGING LIFE;
THE PLEASURE OF MAKING A WILL;
OBSERVATIONS ON SINGING, &c.; AND
EDITOR OF THE LOYAL, NATIONAL, AND SEA SONGS OF ENGLAND.

TO WHICH ARE ADDED,

*An Abstract of the Practical Parts of*
SIR WM. HERSCHEL'S
*Writings on Telescopes and Double Stars, &c.; some Observations thereon, and Original Letters from*
EMINENT OPTICIANS.

LONDON:
PRINTED FOR GEO. B. WHITTAKER,
AVE-MARIA LANE.
1825.

TO

THE MOST HONOURABLE

# THE MARQUESS OF SALISBURY,

ETC. ETC. ETC

*My Lord,*

*Your Lordship having signified your approbation of this Treatise, and granted me permission to dedicate it to you; I avail myself of the welcome opportunity, to express the high sense I entertain of so flattering a distinction, conferred by one "whose praise is fame," and to assure you, that*

*I am,*

*My Lord,*

*Your Lordship's faithful Servant,*

*WM. KITCHINER.*

London, 1825.

# PREFACE.

The Author has written this "*Second Part*" of the Economy of the Eyes, in the same plain and circumstantial manner which he adopted in "*the First Part,*" as he has not heard any objection against it from any Oculist or any Optician excepting One, who, when the Author requested his opinion of it, said,

**O.** "Why, Sir, I think that you have done exactly the contrary of what you ought to have done:—Why didn't you write in learned scientifical terms?—Why, your Book will soon make all the World as Wise about *Spectacles and Opera-Glasses* as I am Myself!"

The Protest of this eloquent Advocate for

"The Pomp of learning and the Pride of words,"

did not discourage me from my purpose, which has never been the petty purpose of pleasing any Party, or any Profession;—neither has Avarice nor Ambition ever tempted me to injure any party, any profession, or any person.

I have endeavoured to write Impartially:—if I have taught the Public how to judge of the Powers which a perfect Instrument ought to possess, I have also stated the difficulties which the Manufacturers have to encounter before they can make it perfect.

I love the good advice given to us by QUINTILIAN, and have done my best to "write so perspicuously, that not only Every body may understand Me, but that

it shall be impossible for Any body not to understand Me."—QUINT. lib. viii.

I can say with the sage SENECA, " I have Learned only to be able to Teach.—The most interesting discovery would have no charms for me, if I only was to be the repository of it"—therefore, I have adopted in this Book, the plan which I originally contrived for " The Cook's Oracle," of assisting the Memory of the Reader by referring from one passage to another; without such *References*, my Book, to have been equally clearly understandable by Persons who have not previously studied the subject, must have been at least twice as big; and instead of being, as it is, compressed into a single snug Duodecimo, could have hardly been contained in a couple of cumbersome Octavos.

I have been regardless of what Time or what Expense it has cost me to pro-

duce my Works—and it is a most cheering reflection to me, that the Confidence with which they have been received, has been commensurate with the Care that I have taken to compose them.

WM. KITCHINER.

*London*, 1825.

# CONTENTS.

## CHAPTER I.



## CHAPTER II.



## CHAPTER III.



## CHAPTER IV.



## CHAPTER V.



## CHAPTER VI.



## CHAPTER VII.

# CONTENTS.

## CHAPTER VIII.



## CHAPTER IX.



## CHAPTER X.



## CHAPTER XI.



## CHAPTER XII.



## CHAPTER XIII.



## CHAPTER XIV.



## CHAPTER XV.



## CHAPTER XVI.

## CHAPTER XVII.



## CHAPTER XVIII.



## CHAPTER XIX.



## CHAPTER XX.

# INTRODUCTION.

---

None of the Elementary or Theoretical Works on Optics or Astronomy*, which I have seen, contain any Directions for the application of various Magnifying Powers to Telescopes of various constructions; or for their proportion to the size of the Instrument, and the nature and distance of the Objects to be observed :—No Man may pretend that he can jump into such Knowledge by *Theorising*—it can only be acquired *Experimentally*, by a person who has perfect Specimens of the various Instruments in his possession at the same time, and has been in the Practice of employing them

"Magno labore, multisque nocturnis vigiliis,"

for the especial purpose of ascertaining what Powers they possess, and to what Objects they are applicable.

"Optical Writers," says *Jesse Ramsden*†, "are

* Except some Papers in the Philosophical Transactions, and a few others which I have quoted in this work.

† See his Paper on *Cassegranian* Telescopes, page 419 of the 69th Vol. of the *Phil. Trans.*, quoted in this work in the Chapter on *Cassegranians*.

usually more Theoretical than Practical"—they have been indeed! almost in the ratio—that Something is more than Nothing, or that the Authors, like shrewd *Jesse Ramsden* himself, have found it easier to amuse their Readers with Assertions, than they found it was to accumulate a series of accurately ascertained Facts, and to shew clearly, how Experiments may be easily made, by which Persons entirely unacquainted therewith may prove the truth of them.

To write, and to collect and arrange the information contained in this Volume (although it may possibly fall short of the expectations of the Reader), has occupied a considerable portion of the Writer's time during a period of Thirty Years—and his Instruments for Experiments, have cost him more than Two Thousand Pounds, for his principal source of acquiring correct information, was to purchase the most perfect Instruments, and try them with his own Eye, which gained its discriminating power only by slow degrees and by extensive experience.

The Author does not regret, but rejoices that he has employed so much Time and Money in this manner; the Pursuit was a Pleasure to him during the time he was engaged therein, and now it is over, he enjoys the satisfaction of reflecting that while he has been hunting on a favourite Hobby, he has found some facts in the fields of Science which have not been gathered by preceding Writers,—which will not only save Persons who may make Optics and Astro-

nomy, either their Business or Amusement,—much Trouble, much Time, and much Expense, but moreover, much straining of their Sight, to no purpose but to prematurely impair it.

The Author's Eye at his age of 47, is as much impaired by the extreme exertion it has been put to in the prosecution of this work, as an Eye which has been employed only in ordinary occupations usually is at 60 Years of Age!—to cultivate a little acquaintance with the particular and comparative Powers of Telescopes requires many extremely Eye-teasing Experiments.

Whatever inexperienced Amateur Opticians may think of this declaration of the Cook's Oracle,—'tis true.

The Author respectfully assures the Reader that these Lucubrations from his *Garret* are the result of Actual Experiments;—like those lately published from his *Kitchen*, they are faithful statements of facts repeatedly proved.

He has been very careful, in constructing every sentence of this work with words which would express his meaning clearly and correctly;—nevertheless,—as he wishes to give those who may do him the honour of perusing this Book, all the Information that he has accumulated, in the most convincing and most satisfactory manner; he has never been contented to offer his mere Assertion, whenever it has been in his power to produce Proofs from the

writings of Experienced Authors, notwithstanding He has been told that some people may say he has done so merely to make his Book bigger—

> "Let Hercules himself do what he may,
> The Cat will mew, the Dog will have his day."

He has endeavoured to convey as much information in as few words as he could without being in danger of being obscure, and to concentrate his work into as small a compass as possible—that it might be given to the Public for as small a sum, and thereby be as generally Useful as possible,—which the fulness of the following pages sufficiently testifies.

The Author humbly and candidly confesses, that after 30 years' experience, there are many things about Telescopes which He cannot account for—and some which he has not met with any Optician who has explained to his satisfaction; notwithstanding, the Reader may have heard a Would-be-thought Philosopher "*say* more in an Hour than he can stand to in a Year," who, upon whatever may be the topic of conversation at the moment—"hath a Mint of *Phrases* in his Brain," and will talk you a torrent of technical terms, and incontinently unload his Imagination with such inconvenient volubility, that a bystander who has not studied the subject which one of these verbose declaimers may be pleased to discuss, cannot choose but suppose that such a sparkling speaker must have actually seen, the

things which he has—merely supposed; and in fact for his Account of which—he has been under much greater obligations to his Imagination, than he has been to his Memory.

The Writer has heard some Gab-gifted children chatter upon these subjects, as fast as a Wilderness of Monkeys do, when those funny fellows fancy that the Nuts are beginning to ripen.

> "Words are like Leaves, where they do most abound
> Much Fruit or Sense beneath is seldom found."

The Reader will meet with plenty of plausible persons who, although they hardly know the *Eye*-end from the *Object*-end of a Telescope, will try hard to make believe, that it is as easy to write a True Essay on Telescopes,—as it is to eat a Good bit of Good Bread and Butter when you have a Good Appetite.

To be accurate, and to be easily understood even by those who have never studied the subject treated on in this Volume, has been the aim of the Author, who fears that his plain phrase will not be so savoury to some who fancy themselves and pass on others as prodigiously profound persons, merely, because they have crammed their Memory with, and amaze their Auditors by repeating a confounding crowd of cramp terms which are only intelligible to those who have been educated in

> "The pomp of Learning and the pride of Words."

The Author's Prayer—has been for the power to write

Truth in terms immediately convincing to All Persons of Common-sense who can

"Spell and Put together."

He has cautiously avoided discussing any point which he has not very deliberately considered, and in almost every instance has proved by repeated experiments—and he takes the liberty to humbly advise Young Gentlemen who may amuse themselves with writing upon Scientific subjects, and Critics who pretend to comment on the Writings of others, of some of whom it is said truly enough, that they are quite as admirable for their Wit, as they are estimable for their Veracity,—and that the Public would not respect them less, if they would sometimes condescend to make sure by careful experiments that their assertions are True,—before they presume to print them and barbarously waste Paper in the propagation of Error.

During the time that the Author was writing this Book, he read with equal surprise and regret in a work on Optics, &c. published not long since, (among other erroneous opinions,) that *Reflecting* Telescopes are lighter* than *Refractors*, because more Light is reflected by *Specula* than is transmitted by *Glass*!!

* When it is said that more Light is transmitted by an Achromatic Object Glass, than is reflected by the Specula of a Reflecting Telescope—the Instruments being of equal aperture and the Magnifying powers being equal—the Author does not mean that

There would be no difficulty in assembling too many specimens of equally unaccountable mistakes which pretenders to Science have published at no very distant period — but the Author's object, is purely the establishment of Truth.

It would greatly diminish the Pleasure which the Writer receives from giving the following pages to the Public, if he thought that they contained any remark which ought to be disagreeable to any Honest Man.

Whenever the cause of Truth has compelled him to protest against any opinion which has been promulgated by a preceding writer — he has taken every pains to perform that part of his Duty, with as much Delicacy and Gentleness as possible.

" 'Tis Excellent to have a Giant's Strength, but it is Tyrannous to use it like a Giant."

> " Who, for the poor Renown of being smart,
> Would plant a Sting within a Brother's heart?"

There is no subject, the Writings on which the Author has examined, in which he has found fewer Facts, than that which he is about to endeavour to illustrate in the following pages—*the Practical part of Optics* is

> " Puzzled with Mazes and perplexed with Errors,"

which those who have attempted to unravel and illuminate by *Theory* unproved by *Practice,* have not

the pencil of rays proceeding from the Achromatic Telescope is bigger than that from the Reflector—but that it is brighter, and consequently makes a more vivid impression on the Eye.—W. K.

diminished — for instance, — as soon as MR. DOLLOND had by many Years of arduous and patient application brought his Discovery of the Achromatic Object Glass to such perfection as promised to reward him for it, that magnificent mechanical Philosopher, the DUKE DE CHAULNES, raved with the noble ardour of immediately pouncing upon our industrious and ingenious Optician's invention, (notwithstanding Mr. D. had obtained a Patent to secure him some fruit from his labour,) and undertook to teach all the World how to make Achromatic Telescopes!!!

This most Noble Duke, persuaded Mr. Dollond to let him have one of his best Object Glasses, which, as soon as His Excellency received, His Grace had cut out of its cell, and the Curves and Densities of the three Lenses composing it carefully measured and weighed; vainly imagining—that once in possession of such *Data*—it would be as easy to make a Telescope, as it is to make a Tube.

How far the Nobleman's project succeeded, may be guessed from the fact, — "that although the Object Glass, as adjusted by Dollond, was a beautiful one—yet that when the Duke re-adjusted it after he had separated it, although it was as good as ever to look at—it was good for nothing to look through!!!

So much was Theory at odds with Practice*, that

* *The Practical Optician* can employ his skill in producing suitable Specula for counteracting each other's errors with respect to

when in possession of the component parts, *the Parisian Sçavans en masse* could not even properly combine them. — Such disappointments, the late Mr. Peter Dollond informed me, have happened to several prodigiously sublime Geniuses.

Many Projects which appear plausible enough, — and pretty enough, — and perfect enough, upon Paper—cut but a monstrous Queer Figure when put to the proof by Practice.

However crude, however imperfectly expressed, some of the following Observations may prove, — notwithstanding the Extreme Care which with unfeigned humility, I avow, I have bestowed in order to be Accurate and Intelligible — I hope, that my Reader will give me credit for having done my best,

the united effect of their separate aberrations, better than *the calculating Theorist* can pretend to direct; for the moment he screws his Eye-tube alternately out and in, beyond and short of distinct vision, he knows the nature of the curves of his specula, and whether the indistinctness arising from aberration is the consequence of too much or too little curvature at the vertex of the large speculum, and can make the final alteration accordingly. This practical dexterity arising out of experience, supersedes the necessity of tedious mathematical calculations, where some part of the data must necessarily be assumed; and it is much to be wished, that *practical* men who have excelled in this particular and in other practical niceties, would initiate their successors in the secrets that promoted their excellence, that posterity may benefit from their successful labours. — Dr. Rees's *New Cyclopædia,* 4to. vol. 35. Art. Telescopes.

to put him into complete possession of all the "Practical Facts" which I have been able to accumulate. But notwithstanding my Work is the result of many Experiments and much Thinking, I am very far from being satisfied with it, and beg that especially the chapter on *Illuminating Power* may be considered as submitted to the Reader rather as a relation of the Author's ideas and opinions on that subject, than as a Collection of indisputably established Facts.

Of the "Castles in the Air," which Theory has built at the expense of Truth,—there are none more numerous, none less substantial, than those which have been imagined by Amateur Opticians.—I have not aimed at amusing such Ingenious Persons with abstruse Algebraic calculations,— by which, if some Writers have succeeded in exciting a few

"Wits and Philosophers, Scholars and Conjurors,"

to admire their amazing erudition—it has been at the unwise expense, of rendering their works entirely useless to the Public.

The humble efforts of the Author, have been to give a plain unvarnished account of the actual results of his own experience. Let Truths interesting to All, be told in Terms intelligible to All.

"PRO BONO PUBLICO."

It is universally lamented, that almost all Arts and Sciences are more or less encumbered with *Vulgar Errors* and prejudices, which Avarice and Ignorance

have unfortunately sufficient influence to preserve, by help (or hinderance) of undefinable, and not seldom *unintelligible,* technical terms—Anglicè, *nicknames*—which instead of enlightening the subject it is pretended they were invented to illuminate, serve but to shroud it in almost impenetrable obscurity.

The Professors of most Arts seem to be fond of keeping up the Mystery of them, and of preserving the accumulated prejudices of ages past undiminished,—one might fairly suppose that those who have had the courage and perseverance to penetrate the veil of Science, were delighted with placing difficulties in the way of those who may attempt to follow them, on purpose to deter them from the pursuit, and that they could not bear that others should climb the hill of Knowledge by a readier road than they did themselves.

Such is *l'esprit du corps,* that as their predecessors supported themselves by serving out *gradatim et stillatim,* and retailing with a sparing hand the information they so hardly obtained, they think it convenient to follow their example; and willing to do as they have been done by, leave the inheritance undiminished to those who may succeed them.

From these most determined and formidable enemies, the lovers of Optics and of Astronomy have as many impediments to contend with as need be; very many more than sufficient to suspend their curiosity on the subject.

The principal prejudice which has confined the use of Telescopes, and the study of Astronomy, to the Observatories of the State and of a few opulent individuals, is, the supposition that an immense apparatus of unmanageable magnitude, not only costly to purchase, but difficult to procure, and troublesome to use, is indispensably necessary to discern what has been described by various Astronomers.

Neither such enormous Instruments, nor monstrous Magnifying Powers, are either made or used, except for mere curiosity, nor will they ever be even mentioned, for any other purpose in future—except to set the Million a wondering!

Most of the principal phenomena of the Celestial Bodies are visible with Glasses of moderate Dimensions;—the rationale of Telescopes has this in common with other things, that what is most worth learning, is easiest learned; and is, like many other sciences, reduced to *a few clear points:*—there are not so *many certain truths* in this World, as some children imagine.

Errors, and Omissions, will no doubt be found, and from enlightened Readers — will meet indulgence—They,—know, how unavoidably,—and how often,—such defects will escape the most persevering industry, and most unremitted attention.

Those who are already well acquainted with the subject, which I have devoted many an hour to illuminate so plainly, that I hope All may easily and

exactly understand, may think I have upon some things, been tediously minute,—but if I had not written so circumstantially and so fully, I could not have enjoyed the main Gratification which I receive from publishing my Book,—which is the Pleasure of hoping that it will give an attentive Reader in a *Few Hours* what the Writer has been collecting *Many Years.*

> "Content, if hence th' unlearn'd their Wants may view,
> The learn'd reflect on what before they knew:
> Careless of Censure, nor too Fond of Fame;
> Still pleas'd to praise, yet not afraid of blame;
> Averse alike to flatter or offend;
> Not free from faults, nor yet too vain to mend."
>
> POPE.

In the course of my Optical pursuits, I have been in possession, and have embraced every opportunity of ascertaining, experimentally, the peculiar powers of Telescopes of all kinds, and I may almost say of all sizes.

Many of the 51 Instruments in the following List, were made at my particular desire, and without limiting the price, as Specimens of what Optical art could produce in Telescopes of various Dimensions and constructions; by Messrs. BERGE, CARY, CUTHBERT, DOLLOND, PIERCE, RAMSDEN, SHUTTLEWORTH, TULLEY, WATSON, &c.

I have not affixed the Makers' names to the Several Instruments, because, although I believe that

every care was taken to render them as perfect as possible—nevertheless some of them have Imperfections which I can speak freely of when speaking merely of the performance of the Instruments, but which I could not do, if I spoke of them as the productions of Persons to whom I am indebted for many of the facts herein stated.—The History of the Telescopes may be interesting in all Countries and in all Ages, long after the Opticians and the Author have been totally eclipsed.

I have earnestly endeavoured to write the Truth, unbiassed by prejudice or partiality to any particular system of Optics or Opticians—to ensure, and to prove this, is another reason why I have not mentioned either the Makers of, nor the Prices which I paid for

THE TELESCOPES EMPLOYED IN THE EXPERIMENTS RELATED IN THIS WORK.

| No. | Description. | Length. Feet | Length. Inches | Aperture in Inches. |
|---|---|---|---|---|
| 1 | Achromatic. | 1 | 0 | 1·1 |
| 2 | —— | —— | | — |
| 3 | —— | 1 | 6 | 1·4 |
| 4 | Gregorian. | 1 | 7 | 4· |
| 5 | —— | 2 | 6 | 7· |
| 6 | Achromatic. | 3 | 6 | $2\frac{13}{20}$ |
| 7 | Cassegranian. | 0 | $7\frac{1}{2}$ | 3· |
| 8 | Achromatic. | 3 | 10 | $3\frac{6}{10}$ |
| 9 | Newtonian. | 7 | 0 | $6\frac{3}{10}$ |
| 10 | Gregorian. | 1 | 0 | $2\frac{1}{2}$ |

| No. | Description. | Length. | | Aperture in Inches. |
|---|---|---|---|---|
| | | *Feet* | *Inches* | |
| 11 | Achromatic. | 1 | 0 | $1\frac{1}{10}$ |
| 12 | ——— | 1 | 5 | $2\frac{1}{10}$ |
| 13 | ——— | ——— | | — |
| 14 | ——— | 2 | 6 | 2· |
| 15 | Gregorian. | 1 | 7 | 4· |
| 16 | ——— | 0 | 9 | $2\frac{1}{2}$ |
| 17 | Achromatic. | 3 | 10 | $3\frac{8}{10}$ |
| 18 | ——— | 2 | 6 | $2\frac{3}{10}$ |
| 19 | ——— | 3 | 10 | $3\frac{3}{10}$ |
| 20 | ——— | ——— | | — |
| 21 | Gregorian. | 2 | 6 | 7· |
| 22 | Achromatic. | 2 | 6 | 2· |
| 23 | ——— | 1 | 11 | $2\frac{13}{20}$ |
| 24 | ——— | 3 | 10 | $3\frac{6}{10}$ |
| 25 | ——— | 5 | 4 | $3\frac{8}{10}$ |
| 26 | ——— | 3 | 10 | $3\frac{6}{10}$ |
| 27 | ——— | 3 | 8 | $2\frac{13}{20}$ |
| 28 | ——— | 2 | 6 | $2\frac{13}{20}$ |
| 29 | ——— | 2 | 6 | 2· |
| 30 | ——— | ——— | | — |
| 31 | ——— | ——— | | — |
| 32 | ——— | 2 | 0 | $1\frac{6}{10}$ |
| 33 | ——— | ——— | | — |
| 34 | ——— | ——— | | — |
| 35 | Gregorian. | 1 | 0 | $2\frac{5}{8}$ |
| 36 | Achromatic. | 5 | 0 | $4\frac{6}{10}$ |
| 37 | ——— | 3 | 10 | $3\frac{1}{3}$ |
| 38 | ——— | 3 | 6 | $2\frac{13}{20}$ |
| 39 | Newtonian. | 7 | 0 | 7· |
| 40 | Achromatic. | 2 | 6 | $2\frac{1}{4}$ |
| 41 | ——— | 1 | 5 | $2\frac{1}{10}$ |
| 42 | ——— | 0 | 10 | — |
| 43 | ——— | ——— | | — |
| 44 | Gregorian. | 1 | 7 | 4· |
| 45 | Achromatic. | 2 | 6 | $2\frac{13}{20}$ |
| 46 | ——— | 3 | 6 | $2\frac{13}{20}$ |
| 47 | Gregorian. | 1 | 0 | 4· |
| 48 | ——— | 0 | 4 | 2· |
| 49 | Herschellian. | 7 | 0 | $6\frac{3}{10}$ |
| 50 | Gregorian. | 3 | 0 | $9\frac{3}{10}$ |
| 51 | Achromatic. | 3 | 9 | $3\frac{6}{10}$ |

## CHAPTER II.

### ACHROMATICS.

Mr. Peter Dollond, the son of the Inventor, informed me that about the year 1760 He met with a pot of uncommonly fine pure *Flint Glass*: it is said that *Crown Glass* was also then to be had of much superior quality than has been made since the cessation of the glass-house at Ratcliffe.

Messrs. Dollonds were then in the meridian of their age and experience, and equally indefatigable and ingenious in their endeavours to improve Optical Instruments.

After numerous experiments,—they could not even then, with these confessedly excellent materials, produce Object-glasses of larger aperture than Three Inches and three-quarters:—such was then, when we are assured that it was much more plentiful than it is now, the extraordinary rarity of good Glass of a large diameter, and of the thickness required,—and the extreme difficulty of precisely ascertaining and working the figure of the curves with that accuracy which is necessary to completely correct the aberration in large apertures.

"Though the curve of *the Concave lens* may be so

proportioned as to aberrate exactly equal to the *Convex lenses*, near the axis; nevertheless, as the refractions of the Crown and the Flint glass are not equal, this equality of the aberrations *cannot be continued to any great distance from the axis*."—Mr. P. DOLLOND's *Letter to Mr. Short*: see *Phil. Trans.* for 1765.

*Mr. P. Dollond* was the Father of Practical Optics—according to the above assertion, the late productions (as it is said) of *pure glass of more than six inches in diameter* will probably not be of much use; from the impossibilty of producing with a larger aperture the due degree of *Defining* Power—without which, the only purpose they are applicable to, is for shewing the Milky Way and Nebula.

Mr. P. Dollond did not extend the diameters of his Object-glasses beyond $3\frac{8}{10}$ inches; except a few of Four inches aperture, of Six, Seven, and Ten feet focus, and the ten feet Achromatic which is now applied to the Transit Instrument at the Royal Observatory at Greenwich, and has a Double object-glass of Five inches diameter, which, Mr. Peter Dollond told me, is the largest, and the only one of that size which he ever made:—Two or Three 10 feet Achromatics, of 5 inches aperture, have lately been made by Mr. G. Dollond, and One by Mr. Tulley. See his Letter in the Chapter on *Illuminating Power*.

I have not seen through an Achromatic with an

Object Glass of larger aperture than $3\frac{8}{10}$ inches diameter, which has entirely satisfied my eye, for observing Double Stars—the Division in Saturn's Ring, &c. and have seen very few of that size—the defining power of which was quite sharp with the whole aperture.

N.B. Many Achromatics, which appear *externally* to be of much larger diameter—are contracted by *a stop within the tube* to a much smaller diameter. (See Cautions to be observed before measuring Magnifiers, in the 16th Chapter of this work.)

It is to be lamented that so many circumstances must combine to the perfect formation of Achromatic* Telescopes.

* "When the Convex and Concave Lenses are both ground and polished, they require care in putting them properly into the Tube, so that they may have their common axis coinciding with the axis of the Eye-glasses, in order that every part of the field of view may be equally distinct and free from colour: and as there will always be some errors of workmanship, and as both lenses, but particularly the flint, may not be perfectly homogeneal, one of the lenses must be turned round in the common cell, till the faults of one lens are observed to correct those of the other as much as possible; which will be known when the vision is most distinct, or the object best defined.

"Should any Colour remain about the edges of the object, the prismatic aberration is not corrected;—and if indistinctness does not take place soon, and at equal distances from the point of distinct vision, when the Eye-tube is moved in and out, the correction for spherical aberration is not perfect.

"In the first place, the focal distances, as well as the particular surfaces, must be very nicely proportioned to the densities, or refracting powers of the crown and flint glass, the dispersive power of which is very apt to vary in the same sort of Glass made at different times, and indeed not unfrequently in different parts of the same pot of Glass — this want of homogeneity is universally complained of by Opticians.

"Secondly, the centres of the two glasses must be placed truly on the common axis of the Telescope, otherwise the desired effect will be in a great measure destroyed. Add to this, that there are sometimes six and always four surfaces to be wrought perfectly spherical; and any person, but moderately practised in Optical operations, will allow that there must be the greatest accuracy through the whole work."—Mr. J. DOLLOND's *Experiments of the Refrangibility of Light.*

The difficulty of obtaining large Object-glasses induced them to make *Binocular Telescopes.* Mr. Au-

"A double Object-Glass is much more easily adjusted for a good central position, and for the counteraction of opposite errors of workmanship and imperfection of glass, than a triple one, and has moreover more light, in consequence of having but four reflecting surfaces; but as it does not admit of any changes of the faces of the final adjustment, the lenses require to be both truly calculated and nicely worked, in order to make the practice correspond with the theory."—Dr. REES's *New Cyclopædia,* vol. 35. Art. Telescopes.

bert had one composed of two Five feet Achromatics, each having an aperture of three inches.

DR. IRWIN says, after a variety of experiments, that objects seen with both Eyes appear only one-thirteenth part brighter than when seen with only one eye.

MR. GEORGE DOLLOND has assured me, that objects seen with both eyes at once, as with a *Binocular Telescope*, certainly appear not only *brighter* but *larger*, as 3 to 2, though the Magnifying power be the same.

The following observations on Binocular Telescopes were given to me by DR. FIRMINGER, who was many years Observer at the Royal Observatory.

" When the Binocular Telescope is well adjusted by looking with each Eye separately through its respective Telescope, and adjusting each to distinct vision; then, if both Eyes be applied at once, the field of the telescope appears enlarged, and the Object viewed much brighter than when seen through either Telescope separately.

" It is difficult to estimate the comparative difference of brightness in the appearance of an object when seen through this construction of Telescopes, when one Eye and one Telescope is applied, and both Eyes at once.

" It has been generally admitted by those who have looked through a Binocular Telescope, that the

degree of brightness with both telescopes is not twice so great as with either telescope separately. Some people have estimated the distinctness and brightness of an object seen through both telescopes at once, to be to the same when seen through either separately, as 3 to 2.

"My observations go no farther than to have remarked, that when looking at a distant land object through both Telescopes at once, the object appears much brighter and more distinct, than when viewed through either of the Telescopes separately."

The Author, having lost the sight of one Eye—is incapable of investigating this subject himself.

*The Forty-six inch* Achromatic*, which established the fame of this kind of telescope, has a Treble Object-glass of $3\frac{6}{10}$ inches aperture, and is composed of two Convex lenses of Crown glass with a Concave of white Flint between them.

Before these were made, the Refracting Telescopes for Astronomical purposes, were of the unwieldy length of at least 35 feet; and the long *Aerial Telescope* of HUYGENS†, which is now in the possession of the Royal Society, to whom Mr. Huygens bequeathed it in his last Will, is 123 feet focus.

In a conversation I had with *Mr. P. Dollond*, a few years ago, he informed me, that when the great *Huy-*

* See an Account of Dollond's 46 inch, p. 54 of the *Phil. Trans.* for 1765, vol. lv.

† See Mr. Huygens's circumstantial Description of his Aerial Telescope, in the *Phil. Trans.* for 1684, in the 13th vol. p. 668.

*genian* glass of 123 feet focus, 6 inches aperture, and charged with a power of 218 times, was in the possession of *Mr. Cavendish*, it was compared with one of his 46 inch treble object-glass Achromatics; and the gentlemen who were present at the trial, said that the Dwarf was fairly a match for the Giant,—the trouble of managing which was tiresome indeed.

HUYGENS called it an *Aerial Telescope*, (see Index,) from its being used without a tube, by placing the object-glass on the end of a long pole, the top of a tree, or roof of a house.

To those who know how important it is that the Eye-glass and Object-glass should be placed precisely parallel to each other, it will be matter of much surprise, how any thing could be seen distinctly with such Unmanageable machines.

*Dr. Derham*, who had *Huygens's* Telescope some time in his possession, says it was excessively difficult to observe distinctly and accurately with it.

The best account I have seen of the performance of this glass, is in Dr. Derham's preface to his *Astro-Theology*, which is written with more quiet Good sense, and the genuine, unaffected spirit of Truth, than any Astronomical Essay which I have perused.—Vide the last number of *The Guardian*.

Dr. D. observes in page 4 of his preface—" I discovered it to be an excellent Glass, which Dr. Hook—and many of our best judges, took to be good for nothing."

The following Table is an abridgment of the Proportions of HUYGENS's Refractors, copied from Dr. SMITH's Optics.

| Dist. of focus Object-glass. | Diameter of Aperture. | Magnifying Power. |
|---|---|---|
| *Feet.* | *Inch and Decem.* | |
| 3 | 0.95 | 34 |
| 5 | 1.23 | 44 |
| 10 | 1.73 | 63 |
| 30 | 3.00 | 109 |
| 40 | 3.46 | 120 |
| 50 | 3.87 | 141 |
| 100 | 5.49 | 200 |
| 200 | 7.75 | 281 |

By comparing this Table of the proportions of the old *Refractors* with the following Table of the *Achromatics*, it will be seen that the Refractor of 50 feet did not bear a greater aperture than the Achromatic of 5 feet *focus*.

FOCAL LENGTHS — APERTURES — ILLUMINATING

PORTABLE ACHROMATIC TELESCOPES MADE

59 ST. PAUL'S CHURCH-

| Name they are usually called by. | | Focal Length. | | Length when in use. | | Diameter of Aperture. | Illuminating Power. | Usual Magnifying Power for Land Objects. |
|---|---|---|---|---|---|---|---|---|
| *Feet* | *Inches* | *Feet* | *Inches* | *Feet* | *Inches* | *Inch Tenths* | | |
| 1 | 0 | 0 | 9 | 1 | 2 | 1·1 | 11 | 16 |
| 1 | 6 | 1 | 1 | 1 | 7 | 1·3 | 16 | 22 |
| 2 | 0 | 1 | 8 | 2 | 4 | 1·6 | 25 | 25 |
| 3 | 0 | 2 | 6 | 2 | 4 | 2· | 40 | 35 |
| 4 | 0 | 3 | 8 | 4 | 4 | 2·7 | 72 | 45 |

ACHROMATIC TELESCOPES FOR

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 6 | 2 | 6 | | | 2· | 40 | 35 |
| 3 | 6 | 3 | 8 | | | 2·7 | 72 | 45 |
| 3 | 10 | 3 | 10 | | | 3·6 | 128 | 60 |
| 5 | 0 | 5 | 3 | | | 3·8 | 144 | 65 |

The respective Powers and particular Uses of the

N.B. The cause of the variation in the price of Telescopes of the same

the Account of the three feet and a half

AND MAGNIFYING POWERS AND PRICES, &c. OF THE

BY G. DOLLOND, OPTICIAN TO HIS MAJESTY,

YARD, LONDON.

| Magnifying Power for Planets. | Magnifying Power with Dr. Kitchiner's Pancratic Eye-tube. | Length when shut up. | | Weight in Ounces. | Price. | | |
|---|---|---|---|---|---|---|---|
| | | *Feet* | *Inches* | | *L.* | *s.* | *d.* |
| 30 | | 0 | 5 | 6 | 2 | 2 | 0 |
| 40 | 25 to 100 | 0 | 7 | 8 | 3 | 3 | 0 |
| 60 | 30 to 120 | 0 | 9 | 16 | 4 | 4 | 0 |
| 80 | 30 to 120 | 0 | 10 | 30 | 7 | 7 | 0 |
| 130 | 30 to 120 | 1 | 2 | 64 | 13 | 13 | 0 |

ASTRONOMICAL OBSERVATIONS.

| | | | | |
|---|---|---|---|---|
| 80 | 50 to 200 | The length of this and the following Telescopes when shut up is a few inches more than their focal length. | | |
| 80, 130, 180 | 100 to 400 | | | £21 to 84 |
| 80, 130, 180 | 100 to 400 | | | £100 to 200 |
| 110, 190, 250 | 150 to 600 | | | Same price as the 46 inch. |

above Telescopes are stated in the following pages.

size — is explained in the Anecdote of the "*Humorous Hosier.*"—See Achromatic—in a few pages further on.

The astronomical Mr. AUBERT, gave an unqualified preference, to the 46 inch, (which has three object-glasses of three inches and three-quarters aperture,) to all other Telescopes: and his liberal mind, and constant attention to these subjects, (he had no less than **36** Telescopes) gave him opportunities of gaining accurate information.

*The* 46 *inch Achromatic,* with a triple Object-glass of 3¾ aperture, was also Dr. MASKELYNE's favourite instrument, and that which he made most use of, and he had a small room in the Royal Observatory* fitted up on purpose for this telescope.

At the Sale of Mr. AUBERT's Astronomical Instruments, which were sold by Mr. Sotheby, July 24, 1806, I purchased the celebrated Achromatic of 46 focus, with a triple object-glass of three inches and three-quarters aperture, (as it is usually called, but which, in truth, is $3\frac{1}{2}\frac{1}{0}$ inches in diameter) which was originally fitted up by *Mr. Ramsden* for the Honourable *Topham Beauclerc,* and *Mr. Ramsden's* name is engraven on the eye-end of the telescope: but *Mr. Peter Dollond* informed me that he made the Object-glass, and, smiling at the time he gave me this information, said, "Yes, that Object-glass is one of the things which is to make me immortal;" and appeared pleased with the permission I gave

* Vide Evans's *Juvenile Tourist,* which contains a very complete account of the Greenwich Observatory.

him to engrave his title to it on the tube of the Telescope.

To have composed such a perfect piece of art, is so honourable to an artist, that, to avoid all appearance of partiality or prejudice to either of these eminent Opticians,—I distinguish it, by the name of the person it was made for, " BEAUCLERC."

This Telescope is, indeed, one of those perfect Instruments which are rarely produced, and only attainable, by a happy concurrence of the various circumstances which combine to form these compound Object-glasses.

For exquisite perfection, we are, in all mechanical matters, almost as much indebted to accident as to art:—for instance, a Watchmaker makes a dozen *Chronometers*, and bestows an equal degree of attention to the finishing of each of them; so much so, that he has reason to hope they will all perform equally well: however, when put to the trial, he commonly finds, that of the dozen, perhaps four, in spite of all his care and pains, will turn out but indifferent Watches; six of them good; and the remaining two extremely fine, fit " to correct old Time, and regulate the Sun:" but why they act with such superior accuracy, he cannot imagine.—In every department of art it is the same, and *the Acmè of perfection, is always accidental,* and not to be attained with undeviating certainty by any rules

I have given this particular account of the performance of my 46 inch treble object-glass,—because—these Instruments are now extremely rare to be met with, as they are much more difficult to make than Double Object-glasses, from having Three lenses, and the difficulty of adjusting them exactly.

There is a *Vulgar Error,* which has pretty generally obtained, that *Treble Object-glasses,* transmit much less light than *Double ones.*

If Theory be true, Treble object-glasses must give more distinct and more Achromatic vision than Double ones, inasmuch as the aberration arising from the spherical figure of the glasses, can be more perfectly corrected, by the refraction of the crown glass (in which the excess is) being divided, by having two lenses of crown glass instead of one.

According to Optical Theory, *Three* object-glasses should give a more distinct and a smaller image of a Star than *Two*—and of Double Stars, their apparent distances from each other are increased in proportion as their apparent diameters are diminished.

The difficulty of obtaining good Glass of 3¾ inches in diameter, and of making these 46 inch Telescopes for a price which would suit the general demand, induced the Makers to introduce the present 3½ telescopes, with a Double Object-glass of 2¾ in diameter, which answer many of the general purposes of common observers—and for the *minutiæ* of Astronomy they increased the length of the 46 inch to 63

inches, enlarged its aperture two-tenths of an inch—and made the Object-glass Double—and the 5 feet, as they are termed, are certainly considerably more powerful, though not quite so convenient as the 46 inch. (See the Chapter on *Saturn.*)

As soon as it became the fashion not to make Treble Object-glasses of 3¾ aperture, it was the fashion to say, that a Double Object-glass of Two inches and three-quarters aperture, would perform almost as much as a Treble one of Three inches and three-quarters.

However, the fact is, a fine Treble object-glass of three inches and three-quarters aperture, is almost as much lighter than a Double one of two and three-quarters,—as that is than one of two inches.—See Table of Illuminating Power, *i. e.* the 5th column in the Table of Powers, &c., of Achromatic Telescopes, at page 24.

I had, a few years since, in my possession, a portable telescope in a sliding Tube, which Mr. Ramsden made for the Honourable Stewart M'Kenzie, of twenty-seven inches focus, with a treble object-glass of two inches and one-quarter clear aperture. I found this singularly superior to any double object-glass of that diameter that has come within the *focus* of my observations: *i. e.* I have seen minute celestial objects more easily and distinctly with it.

As it may be interesting to some to know *with how small an aperture and power the faint and close*

*Double Stars have been discerned,* I have transmitted, from my Journal, some of the observations I made with this little Telescope for that purpose.—(See the Observations on *Rigel* in the Chapter on *Double Stars.*) Indeed I never remember to have seen this difficult object, easier than with this little Glass.—(See Observations on *Rigel,* in Index.)

For TESTS *of the Goodness of Achromatic Telescopes,* read the Chapters on "Double Stars," on "Saturn," and "Magnifying Powers," and on "Choosing Telescopes."

## CHAPTER III.

SPYING-GLASSES — PORTABLE ACHROMATIC TELESCOPES FOR SEA AND LAND, AND NIGHT-GLASSES.

THE smallest Telescopical Instrument which I have seen, that is actually useful, is

"THE INVISIBLE OPERA-GLASS,"

this is a great acquisition to Travellers, especially to *Short-sighted Persons and Artists*, &c., who wish to discern the distinct outline of objects at short inaccessible distances; *i. e.* for an Architect to see the exact outline of a Building a quarter of a mile off—or to examine the pointing, &c. of the walls of upper stories, &c.

When shut up in its case, this little glass is only 2 inches in length;—when in use, not more than 3 inches:—it has a single plano-convex Object-glass $\frac{6}{10}$ of an inch in diameter, its Magnifying power is about 3 times, and it is sold for 12*s*.

For *Distant Objects*, extremely *Short-sighted* Persons require A Small Opera-Glass; which having an adjustable focus, if it only magnifies *Twice*, will be infinitely better than any single Concave, because it can be exactly adapted to various distances. (See "ECONOMY OF THE EYES," p. 103.)

The next Optical instrument of this kind is the

### SMALLEST SIZED PERSPECTIVE.

This is made with an Achromatic Object-glass of $\frac{3}{4}$ of an inch in diameter, with a Single Eye-glass, which makes it magnify about five times :—a Double Eye-head is also fitted to this Perspective, which gives it a lower and a higher power—and it may likewise have a deep concave fitted to it, which will make it magnify enough to shew two of the Moons of Jupiter.

There is a second and third size Perspective, but the second is very little superior to the smallest—and the Largest is inferior to the portable *One Foot Telescope,* and not much shorter, though much heavier.

A good *Achromatic Opera-glass,* that magnifies four times, is a very pleasant prospect Glass.

For a particular Account of the Construction and Powers of OPERA GLASSES and SPECTACLES, see the First Part of "THE ECONOMY OF THE EYES," where the subject is minutely and plainly illustrated for those who have never made Optics their study.

### PORTABLE ACHROMATIC DAY TELESCOPES IN SLIDING TUBES.

*The following instruments should all be made with POLYCRATIC sliding Eye-tubes, which will vary the magnifying power.—See POLYCRATIC in the Index.*

The smallest size is the *one Foot.*—For a descrip-

tion of Aperture, Power, and Price of which, see the Table of Achromatics.

THE 18 INCH

is a more powerful Instrument, by applying to it a power of 40, you will see the Satellites and Belts of *Jupiter*—and the Ring of *Saturn*—*the Pancratic Eye-tube* may be applied to this Telescope, and gives a range of magnifying power, for Day objects and Astronomy, from 25 to 100 times; with the latter several Double Stars are visible. (See *Chapter on Double Stars.*)

THE 2 FEET

is still more superior to the 18 Inch, than that is to the One Foot, both for Terrestrial and Celestial purposes; with this telescope the Celestial objects mentioned above are easily visible; and for ordinary use, distant Objects are almost as well seen with it as with a larger glass—unless the latter be upon a stand, and the air be extremely clear.—Such is the impediment of the Atmosphere of this country, that, at a greater distance than three miles, you can hardly tell a good Telescope from a bad one, unless the air be unusually transparent.—This is the largest telescope that can be used without a stand and an adjusting screw:—which appendages are indispensable in all glasses that magnify more than Twenty-five times. *Mr. Price of Fetter Lane,* made me an adjusting screw for a

sliding Telescope—with Teeth and Pinion—separate from the telescope, and introduced between the first and second sliding Tubes; this must be done very carefully, so as not to interfere with the centering of the Eye-tube and the Object-glass. (See OBSERVATIONS on PORTABLE STANDS, in the Chapter on MAGNIFYING POWERS, and on ADJUSTING SCREWS, in the Chapter on "HOW TO SET OR ADJUST TELESCOPES.") The magnifying power usually put to this Glass is stated in the preceding *Table of Achromatics.*

THE 3 FEET

is a still more powerful Glass, but its weight and length render it inconvenient to carry, and it cannot well be used without a Stand and an Adjusting Screw. See the Account of *the 2½ feet Achromatic,* in the Chapter on Magnifying Power. The 2½ feet, or 30 inch, is in fact the same Object-glass that is put to this 3 feet in a sliding Tube.

THE 4 FEET:

The Observations on the last Telescopes apply with double force to this—it is useless without a stand and an Adjusting Screw. See the account of the 3½ *feet Achromatic*—which has the same Object-glass in a single Tube that is put into the 4 feet sliding Tubes.

## TELESCOPES TO BE USED AT SEA.

Nothing has contributed more to the success of navigation, the knowledge of distant parts, and the ease and certainty of finding again the Island, or Place before discovered, than the Optical and Mathematical Sciences. The improvements made in the various instruments appertaining to each, have produced a great facility in bringing nearer to a state of perfection, the pursuits of every adventurer in search of Knowledge.

The Telescope is an instrument that affords pleasure and profit, and has often proved the means of safety either from the dangerous effects of a storm, or an enemy's ship in sight. So that now it is become a matter indispensable for every Vessel to have one or more telescopes; and every officer is careful to be in possession of a good Glass. Telescopes for the Sea service are made of different dimensions, according to the purposes for which they are applied.

The Telescope in ordinary use is of Two feet focal length, with a magnifying power of about 24 times, and the diameter of the Object-glass, which is treble, is $1\frac{6}{10}$ inch. This is by seamen denominated a Deck Glass, a Look-out, or a Mast-head glass; and is scarcely ever out of the officer's hand: the size and shortness of it enabling a Midshipman to secure it under his jacket, and take it aloft with safety. I have

been informed that the appointment of the late Sir Home Popham to go out on a Cruise and Station for three years in the West Indies, authorised him to take under his care forty or fifty Youths, to instruct them in the practice and manœuvres of nautical science, who had previously received a suitable education for it; Sir H. ordered that each of them should be furnished with a Hadley's Quadrant, a Case of Mathematical drawing instruments, and a best-made Two feet Telescope.

A complete Case of SEA TELESCOPES consists of the largest size, Three feet, with an Object-glass of 2¼ inches diameter, having a spare eye-tube, to be occasionally inserted in the Eye-drawer, for Hazy weather. The Magnifying powers are 20 and 28 times, and the price seven guineas: also, a Three feet Telescope of the usual size, with an Object-glass of 2 inches diameter, and Magnifying 25 times; price five guineas. A best Two feet Telescope, magnifying 24; price three guineas. A Night or Day Telescope, but this may be more properly termed a Hazy-weather-glass; it has a very wide field of view, with a magnifying power not more than 15 times; which is found very useful whenever the Haze, or obscurity, prevents the use of larger Telescopes; price four guineas.

A NIGHT-GLASS, these made with a single convex lens of three inches, or three inches and a half diameter, have been found eminently serviceable; for though the Object is shewn inverted, yet with a

little practice it may be kept in view throughout the night; the price is three guineas.

A Telescope with sliding tubes, of 18 inches focal length, magnifying about 24, in a fish-skin case, shutting up to the length of seven inches—price two guineas and a half.

A Mahogany case to contain the above-mentioned Telescopes, neatly packed, with lock and key, is charged one pound eighteen shillings; the whole costs £27. 12*s*. 6*d*.

A Telescope of 4 feet focal length, with an Object-glass of 2¾ or 3 inches diameter, having three different Eye-tubes, and magnifying thirty, fifty, and eighty times, for the purpose of viewing eclipses of the Satellites of Jupiter; can seldom be used with advantage at Sea, as it requires a firm stand for the glass, and a steady position for the observer; both of which are prevented by the continual motion of the Vessel; yet such are of peculiar service when the object is very far distant, and the intervening medium sufficiently clear.—The price is from twelve to eighteen guineas. These are the principal Telescopes used at sea, besides which there are some inferior, fitted up with Octagon mahogany tubes, having only low powers. These generally are put into the hands of young sailors, who, when they have learned how to use, and take care of their telescopes, may have another more valuable entrusted to them.

THE NIGHT-GLASS

derives its title from being useful on board a Ship on clear Nights, for the purpose, as the Sailors term it, of sweeping the horizon, and thereby discovering a ship at sea, or object on the shore, when a Telescope of a different construction would not enable them to do so.

The Night-glass most generally in use, is constructed with three glasses—a single object-glass, and two eye-glasses, and not achromatic, nor is it essential that it should be, as the coloured rays are not perceptible with so weak a light, and as there is a less thickness of glass for the rays of light to pass through, the object becomes more visible.—The eye-glasses are of large diameters, for the purpose of giving a large field of view, and the magnifying power just of sufficient strength to render the object distinguishable.—The object is inverted, but to those sailors who have acquired, by practice, the use of this Telescope so as to enable them to follow the object, the arrangement is of no importance. The Telescopes are made of different dimensions, the smallest being 1 foot 3 inches in length, and 2 inches in diameter.

The Second, or general size is 2 feet in length, and 3 inches in diameter.

The Third size is 2 feet 6 inches in length, and 4 inches in diameter: the largest size is by most people

considered the best, as it has a much larger field of view, and a greater quantity of light—their prices, differing according to their size.—There is also another Night-glass, called the erect Achromatic, which differs from the other in as much, that it shews the object in its proper position and free from colour, which renders it useful in the day-time; the field of view and magnifying power being the same as the Second size before described, this has been much approved by those sailors who have not the art of using the inverting Night-glasses.—Night-glasses have also been used by Astronomers for the purpose of discovering any novelties among the different arrangements of the Celestial bodies, and by those whose sight will not permit them to distinguish the arrangement of the stars without optical assistance. *Night-glasses must be adjusted and marked for different distances in the Day-time;* it is very difficult, indeed it is almost impossible, to get the exact focus, unless on a bright Moonlight night.

## CHAPTER IV.

### THE THREE AND A HALF FEET AND THE FIVE FEET ACHROMATIC TELESCOPES.

THE *smallest Achromatic* that can be used for *Astronomical* purposes, without overmuch teasing of your Eye, is the 3½ feet, which are now usually made with Two object-glasses of $2\frac{7}{10}$ inches in diameter. With this Telescope many of the principal celestial phenomena may be perceived: — for I would make a distinction between "*Seeing*" and "*Perceiving*"—I use the former term when an object is *Seen* plainly, and the latter when it is only scarcely Perceivable.

Some objects which are easily and perfectly visible in a 5 feet Achromatic, with an aperture of $3\frac{8}{10}$, are hardly perceivable with a 3½ feet, which has an aperture of only $2\frac{7}{10}$—the *Illuminating* power of the former exceeding that of the latter as 144 does 72.— See the fifth column of the *Table of Achromatics*, at page 24, and the Chapter on *Illuminating Power*: —, others, which do not require much *Illuminating* power, may be seen as well with the latter as with the larger Telescope.

### THE THREE AND A HALF FEET.

*The usual Day Eye-tube* of this Telescope gives it

a Magnifying power of about 45 times—with this low power the field of view is large, and the vision is very brilliant — and from the vivid impression which objects make upon the Eye, people say that it is very clear, and those who are unacquainted with the relative effects of various magnifiers, are in general better pleased with such a low power than with a higher power—the advantage of which is not at first so striking—until applied to the attentive examination of some minute object, when the advantage of a due degree of Magnifying Power becomes evident—and the Day Eye-tube usually put to a 2½ feet Achromatic, which makes a 3½ feet magnify about 60 times, will be found far superior.

A *Pancratic Eye-tube* is made for this Telescope, which produces in a very perfect manner all the intermediate degrees of Magnifying power between 60 and 240, for either Terrestrial or Celestial purposes.—See the Chapter on the *Pancratic Eye-tube*.

The Magnifiers usually put to this Instrument for Astronomy, are 80, 130, and 180. To these I would recommend the addition of

A *Comet Eye-piece*, magnifying about 15 times,

A *Moon Eye-piece* of 40,

A Compound Eye-tube of 250, for Double Stars, &c. and a Polycratic Wheel containing 6 Convex lenses, magnifying 80, 130, 180, 250, 350, 440.—These particular powers are recommended to give an opportunity of comparing the *Single lenses* with the Eye-tubes

which contain 2 glasses. Those who are anxious to see the effect of higher Magnifiers, may have another Circle, magnifying 5, 6, 7, 8, 900, and 1000 times — but there is No Object that will be seen so well with them as with the power of 250 or at most 350.

OBS. If you wish to have an Object-glass that will bear a high power—ask no questions about the *Price* of any Instrument which you are at all anxious about the *quality* of, — consider yourself fortunate if you obtain it. This Advice applies still stronger to the 5 feet Telescope.

I would hope that the preceding observation is quite superfluous, had I not, in the course of my residence of nearly half a century on this Planet, seen so many instances of People being so extravagantly fond of Bargains—and did I not still remember the anecdote of the "*Humorous Hosier,*" — who caught crowds of Customers, by placing in his window the following placard—

"*The Cheapest and Best Stockings sold here.*"

This brought flocks of Bargain-hunters to his Counter—"Let us see some of your Cheapest and Best Stockings?"

HOS. "There is a pair of each, these, are a Shilling — those are a Guinea a pair."

The Writer respectfully assures the Reader, that the Quality of *Telescopes* varies in quite as many degrees as that of *Stockings.*

Read the Chapter on Magnifying powers and Eye-

pieces. For Tests of the goodness of Achromatic Telescopes—see Obs. in the *Chapter on "Magnifying Power,"* and on *"Choosing Telescopes"* — on *"Saturn"* — and Mr. Wm. Walker's Letter in the Chapter on *"Double Stars."*

In the Table at the End of the Chapter on Illuminating Power, the Reader will find that a Reflector to be as light as the 3½ Achromatic above described, must have an Aperture of 4½ inches in diameter.

### MR. DOLLOND'S DESCRIPTION OF THE FIVE FEET AND THE THREE AND A HALF FEET ACHROMATIC REFRACTING TELESCOPE, MADE BY HIM.

"The Telescope is supported in the centre of gravity, with its rack-work motions, and mounted on its mahogany stand, the three legs of which are made to close up together by means of a brass frame, which is composed of three bars, connected together in the centre by three joints, and also to the three legs of the mahogany stand by three other joints, so that the three bars of this frame lie close against the insides of the legs of the mahogany stand when they are pressed together, for convenience of carriage.

"The brass pin, under the rack-work, is made to move round in the brass socket, and may be tightened by means of a finger-screw, when the Telescope is directed nearly to the object intended to be observed. This socket turns on two centres, by which means it may be set perpendicular to the

horizon, or to any angle required in respect to the horizon; the angle may be ascertained by the divided arch, and then made fast by the screw. If this socket be set to the latitude of the place at which the Telescope is used, and the plane of this arch be turned on the top of the mahogany stand, so as to be in the plane of the meridian, the socket being fixed to the inclination of the pole of the earth, the Telescope, when turned in this socket, will have an equatorial motion, which is always very convenient in making astronomical observations.

" It has also a stand to be used on a table, which may be more convenient for many situations than the large mahogany stand. The Telescope, with its rack-work, may be applied to either of the two stands, as occasion may require, the sockets on the top of both being made exactly of the same size. The sliding rods may be applied to the feet of the brass stand, so that the Telescope may be used with the same advantages on one as on the other.

" The tube may be made either of brass or mahogany, is three and a half feet long. The achromatic object-glass of three and a half feet focal distance has an aperture of two inches and three-quarters.

" The larger size is with a tube five feet long, and has an achromatic object-glass of three inches and three-quarters aperture.

" The Day eye-tube contains four eye-glasses, to be used for day, or any land objects.

"There are three eye-tubes, which have two glasses in each, to be used for astronomical purposes. These eye-tubes all screw into the short brass tube at the Eye-end of the Telescope. By turning the button or milled head, this tube is moved out of the larger, so as to adjust the eye-glasses to the proper distance from the object-glass, to render the object distinct to any sight with any of the different eye-tubes.

"The magnifying power of the Three and Half Feet Telescope with the eye-tube for land objects is 45 times, and of the Five Feet, for land objects, 65 times: with those for astronomical purposes, with the Three and Half Feet, the magnifying powers are 80, 130, and 180; and for the Five Feet, 110, 190, and 250 times.

"Stained glasses, are applied to all the different eye-tubes, to guard the eye in observing the spots on the Sun. These glasses are to be taken off when the eye-tubes are used for other purposes.

"The rack-work is intended to move the Telescope in any direction required, and is worked by means of the two handles. When the direction of the tube is required to be considerably altered, the worm screws, which act against the arch and the circle, must be discharged; then the screw, being loosened, the pin of the rack-work will move easily round in the socket.

"For the more readily finding or directing the Tele-

scope to any object, particularly astronomical objects, there is a small tube or telescope, called the Finder, fixed near the eye-end of the large Telescope. At the focus of the object-glass of this finder there are two wires, which intersect each other in the axis of the tube, and as the magnifying power is only about six times, the real field of view is very large; therefore any object will be readily found within it, which being brought to the intersection of the wires, it will then be within the field of the Telescope.

"In viewing astronomical objects (and particularly when the greatest magnifying powers are applied), it is very necessary to render the Telescope as steady as possible; for that purpose there are two sets of brass sliding rods. These rods connect the eye-end of the Telescope with two of the legs of the stand, by which any vibrations of the tube, that might be occasioned by the motion of the air or otherwise, will be prevented, and the Telescope rendered sufficiently steady for using the greatest powers. These sliding rods move within one another with so much ease as to admit of the rack-work being used in the same manner as if they were not applied."

N.B. The above is a description of the Stand usually put to these Telescopes; there is a superior Equatorial Stand invented by the present Mr. Dollond, which is a very beautiful and steady piece of workmanship.—W. K.

MAGNIFYING POWERS OF MY FIVE FEET ACHROMATIC TELESCOPE, THE DOUBLE OBJECT-GLASS $3\frac{8}{10}$ DIAMETER, AND 63 INCHES FOCUS, MADE BY THE LATE MR. PETER DOLLOND.

| | |
|---|---|
| Longest Day Eye-tube . . . . | 60 |
| Shortest, the Day Eye-tube usually put to a $2\frac{1}{2}$ feet Achromatic | 90 |
| Pancratic . . . . . . . | from 130 to 500 |

MAGNIFIERS FOR ASTRONOMY.

| The Time a Star is passing through the Field of View | Compound E. P. two glasses. | 1st Eye-glass used alone. | 2d Eye-glass used alone. | Uses. |
|---|---|---|---|---|
| Minutes. Seconds. | | | | |
| | 44 | 58 | 28 | Sun, Moon, Nebula. |
| 2 33 | 60 | 84 | 38 | Ditto. |
| 1 45 | 100* | 150 | 54 | Planets. |
| 1 30 | 130 | 190 | 76 | Ditto. |
| | 160 | 210 | 88 | Do. when near the meridian. |
| | 190* | 270 | 82 | Do. when close to ditto. |
| 57 | 250* | 380 | 150 | Double Stars. |
| | 350 | | | Ditto. |
| There is no stop in this Eye-piece. } 37 | 450 | 630 | 270 | Ditto. |
| Cavallo's Micrometer | 45 | | | |
| 1st Single Lens | | 50 | | |
| 2d, | | 100 | | |
| 3d, | | 160 | | |
| 4th, | | 210 | | |
| 5th, $\frac{1}{10}$ of an inch focus. | | 630 | | |
| 6th, $\frac{1}{22}$ ditto. | | 1386 | | |

The Compound Eye-tubes in the first column to which a *Star* is attached, are those usually given with a 5 feet Achromatic.

*By taking away the 2d Glass* and using the 1st only, you will have the powers given in the 2d Column, or nearly so — for the proportions of the Glasses in these compound Eye-tubes are not always exactly alike.

*By taking out the first Eye-glass*, and using the second alone, you will obtain the powers put down in the 3d Column.

*The time a Star is passing the field*, in these Eye-pieces, which is given in the 1st Column, may not exactly accord with the Eye-pieces, of other Telescopes, as it depends partly on the Stop in the Eye-tube — with my Eye-tube, which magnifies 250, it passed in 28 Seconds — but with 450, *without any Stop*, it was 37 Seconds.

The Instrument which I have just described is as perfect a 5 feet Achromatic Telescope as I have seen, and is one of the *chef-d'œuvres* of the late Mr. Peter Dollond — who thus speaks of it, to (the Gentleman he sold it to) Mr. G. Hodgson, F.R.S. (of whom I purchased it), in his Letter, which is now before me, dated Nov. 11, 1803. — "It has been made 10 years, and I can say that it is one of the best I ever made, and such as I cannot expect to be able to equal."

This is, I believe, as perfect an Instrument as Art

can produce—and therefore, what I have stated of its powers, are quite the maximum of what an Achromatic Telescope of such an Aperture and such a length can perform with the most favourable circumstances.—The highest power I have applied to *Saturn* in the finest nights (with advantage) is 190.

In the Table of the proportions of HUYGENS's Refractors, which I have copied from Dr. SMITH's Optics, in p. 23 of the Introductory Chapter on Achromatic Telescopes, the Reader will see that of the single Object-glass which had an aperture of $3\frac{8}{10}$ inches, and which had a focal length of 50 feet, the highest Magnifying power was 141.—This calculation was made for an Huygenian Eye-tube, composed of two plano-convex Lenses and for observing Planets.

The highest power which I have usually or usefully applied to *Double Stars* is 400.—(*See Chapter on Double Stars.*)

Were I to order a Five Feet Achromatic, I would have the Aperture which receives the Eye-tubes large enough to admit such an Eye-tube as is usually put to an Inverted Night-glass—but not to magnify with the 5 feet above 15 times, which would be the best that could be applied for Comets—Nebula—the Milky Way, &c. I would have another such power of 30,—and the Eye-pieces mentioned in the preceding Table, only the single Lenses should be in a Polycratic circle similar to that which I have de-

scribed in the Account of the Three and a Half feet Achromatic.

The following is *Sir George Shuckburgh's* account of the 5 feet Achromatic Telescope made by *Mr. J. Ramsden*, for his Equatorial, which is now in the Royal Observatory at Greenwich.

"The Object-glass is a well-corrected double Achromatic, whose joint focus is 65 inches with an aperture of 4·2 inches, has two sets of eye-glasses, one single, the other double—of the latter six from 60 to 360 times; of the former five from 150 to 550—and a prism eye-tube of 100—the lowest of the compound eye-tubes, a power about 60, is generally used for transits and polar distances; for telescopical observations of the planets 400 seems near the maximum that this glass will bear: with 500 the image is not so well defined; with 200 and 300 it is beautifully distinct and bright."—*Phil. Trans.* vol. lxxxiii. pp. 103 and 104.

I think that there must be some miscalculation of the Magnifiers mentioned in the preceding account—as I have before said, my 5 feet Telescope is as perfect an Instrument as art can produce, and with it 190 is quite as high a power as is agreeable to my Eye when it is pointed at a Planet; Sir *G.* Shuckburgh's Object-glass is $\frac{4}{10}$ of an inch larger than mine, but that increase of its aperture will go but a little way towards making up the difference between

the magnifying powers of 190 and 300, with which latter, he says, his Telescope is "beautifully distinct and bright;" and mentions 400 as near the maximum for observing Planets — I have never seen any Telescope which could bear more than 250 for Planets — the Atmosphere prevents it.

A Reflector to be as light as the above-mentioned 5 feet Achromatic must have an aperture of at least 5½ inches.—See the Obs. following the Table at the end of the Chapter on Illuminating Power.

## CHAPTER V.

### GALILEAN TELESCOPES, AND OF CONCAVE AND CONVEX SINGLE EYE-GLASSES.

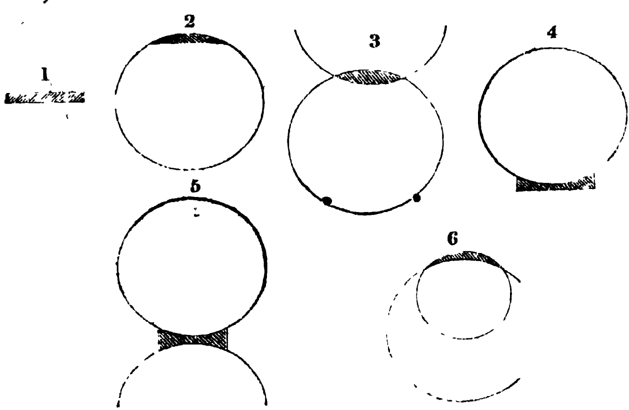
THE original *Galilean* Telescope, of which the optical instrument which we now call an Opera-glass is a miniature, was composed of a Plano-Convex *Object*-glass—and a single Double Concave *Eye*-glass—and has been said to transmit *much* more light than an Huygenian Telescope of the same aperture, which has one or two convex Eye-glasses.—If it be *much* lighter—which it does not appear to be to my Eye, it may be partly accounted for from another cause than that usually assigned: the Concave Eye-glass is generally made of *White Flint*, and it is the thinnest part of it which is employed: a Convex is usually formed from *Green or Crown Glass*, and the thickest part is in use.

However, in the name of Common Sense, if there is any Truth in the asserted surprising superiority of *Concave* Eye-glasses, how has it come to pass that they are never used? If they are really so superior to *Convexes*, surely, instead of Nobody, would not Everybody use them?

I shall now open my Case of *Concaves*, by reciting all the Pleadings I have found in their favour—and then state my own Experience thereon.

## FORMS OF VARIOUS LENSES.

" A LENS is any transparent Substance of a regular Form through which Light may be transmitted, or refracted ; those in common Use are of Glass, ground and polished to a proper Figure, of which there are six different Sorts; as (1.) a *Plain Lens*, both whose surfaces are parallel to each other. (2.) A *Plano-Convex*, consisting of one *Plain* and the other a *Convex*, or *Spherical Surface*. (3.) A *Double Convex*, both whose surfaces are of a Convex, or spherically round Form. (4.) A *Plano-Concave*, with one side Plain, the other a spherically hollow or *Concave Surface*. (5.) A *Double Concave*, both whose surfaces are spherically *Concave*. (6.) A *Miniscus or Periscopic*, which has one surface *Convex*, the other *Concave*."



CONCAVES.

"As they are very thin in the middle, the rays are less liable to be disturbed by the irregularities in the substance of the Glass in passing through it; and also since here we view not the image of Objects—but the objects themselves, by rays coming directly from them, without crossing or interfering with each other; it follows that on both these accounts, we have a clear and most distinct view of an object by this Telescope. And hence it is, that we can sometimes see *Jupiter's Satellites* very plain in a Telescope of this sort not above 20 or 24 inches long, when one of 4 or 5 feet of the common sort, with convex Eye-glasses, will scarcely render them visible."—B. MARTIN's *New Elements of Optics*, 8vo. 1759, p. 18.

Mr. Ben Martin's Theory is excellent, but it is not true, — the most probable reason why He could not see as well in the Astronomical Telescope as in the Galilean, was, that the former must have been an extremely badly constructed Telescope; and the following quotation, from page 86 of Mr .M.'s book applies aptly enough in this place: "I believe there are but few people who will pretend to make a Telescope in FACT, as perfect as it is in THEORY.

SIR WM. HERSCHEL'S REMARKS ON CONCAVES.

In page 28 of the lxxxivth vol. of the Phil. Trans. in Dr. Herschel's Observations on Saturn — the Reader will find the following remarks on *Concaves*.

"I tried several Double and Plano-*Concave* Eye-glasses, but found them all defective in figure except one, and that being *of One inch focal length*, the power was too low to expect seeing the belts of Saturn with it. *The smallness of the field of view in Concaves*, when applied to Astronomical objects, is not so disagreeable as it is generally supposed to be; for the Eye may have a motion before the Lens, and by that means a small luminous object, when all the rest of the field is dark, and while the Telescope remains in the same situation, may be seen for as long a time, passing through the field of a *Concave* Eye-glass, as it can in a *Convex* one; whereas with the latter, it is well known that such a motion of the Eye can be of no use."

In page 58 of the same paper, Dr. H. observes,— "I tried 5 new *Concave* Eye-glasses, but they all proved defective in figure; with one of them, power 360, I saw the quintuple belt pretty well. With regard to the field of view they are full as convenient as *Convex* glasses.

"With regard to the Eye-glasses, when merely the object of saving light is considered, I can say from experience that *Concaves* have greatly the ad-

vantage of *Convexes*, and that they give also a much more distinct image than Convex glasses.

"This fact I established by repeated experiments about the year 1776, with a set of Concave Eye-glasses I had prepared for the purpose, and which are still in my possession.

"The glasses, both double and plano-concaves, were alternately tried with convex lenses of an equal focus, and the result, for brightness and distinctness, was decidedly in favour of the concaves.

"For the cause of the superior brightness and sharpness of the image which is given by these glasses, we must probably look to the circumstance of their not permitting the reflected rays to come to a focus.

"Perhaps a certain mechanical effect, considerably injurious to clearness and distinctness, takes place at the focal crossing of the rays, in Convex lenses. p. 296.

"I have occasionally availed myself of the light of *Concave Eye-glasses*, but a great objection against their constant use is, that none of the customary Micrometers can be applied to them, since they do not permit the rays to form a focal image. *Their very small field of View* is also a considerable imperfection; in observations, however, that do not require a very extensive field, such as double stars, or the satellites of Saturn, and the Georgian planet, this inconvenience is not so material.

"The magnifying power by which the satellites of the Georgian planet were discovered was only 157*."—Dr. HERSCHEL, in p. 298 of vol. cv. of the *Phil. Trans.*

## THE AUTHOR'S OBSERVATIONS ON CONCAVE AND CONVEX EYE-GLASSES.

Experiments with my own Eye have informed me that when the *Moon of Jupiter* can be seen with a *Single Concave*—they may be as easily seen, not only

* "About the same time that the experiments on *Concave* Eye-glasses were made, I tried also to investigate the cause of the inferiority of the *Convex* ones; and it occurred to me, that an experiment might be made to ascertain whether the rays of light in crossing, jostled against each other, or were turned aside from their right-lined course by inflections or deflections.

"With a view to this, I directed a 10 feet telescope to some finely engraved letters, put up at a convenient distance. A *Convex* eye-glass was fixed to a skeleton apparatus, which left the focal point freely exposed. A *Concave* mirror was placed so as to throw the focus of the sun's rays upon the focal image of the telescope, where, meeting with no intercepting body, they would freely pass through it at right angles. Then a screen being placed to keep off the solar rays, I fixed my attention upon the letters viewed in the telescope, and the screen being alternately withdrawn and replaced, *I could perceive no sensible alteration in the brightness or distinctness of the letters*; hence I surmised, that the rays of light did not sensibly jostle in an instantaneous right-angled passage, but that possibly they might suffer inflections or deflections in their crossing at the focal point, on account of their being longer in collateral proximity."—Dr. HERSCHEL, in *Phil. Trans.* vol. cv. note at foot of page 297.

with a single *Convex* of the same focus, but with the usual compound Astronomical Eye-piece (of like magnifying power) as usually made on Mr. Huygens's plan, with *two Plano-Convexes;* moreover, so little light and so little magnifying power is required, that you may see them in the common one foot Achromatic Spying-glasses of about one inch aperture, with the usual Erect Eye-piece, containing *Four Convex* Lenses.

I have often seen the Satellites in an Achromatic Finder of $\frac{3}{4}$ of an inch aperture, and an eye-piece composed of two convex lenses with their plane sides outwards, which magnified about 10 times, —indeed, I have seen two of the Satellites with one of the smallest-sized Perspectives.

*The Belts* require much more Magnifying and Illuminating Power than *the Satellites of Jupiter.*

The Belts of Jupiter are scarcely discernible in a one foot Achromatic—but may be seen with an 18 inch of $1\frac{3}{10}$ aperture and power of 40—and are easily visible in a two feet with an aperture of $1\frac{6}{10}$, with power of 30 to 60.

However, Mr. Martin's assertion has been quoted repeatedly, and has passed current ever since he printed it—this is, I believe, the very first time that it has been contradicted:—if any of my Readers wish to make an experiment, to ascertain the comparative illuminating Power of a single Concave, a single Convex, and the usual Astronomical Eye-tube, they

may, for a few shillings, be furnished with a *Concave* and a *Convex* Eye-glass of exactly the same magnifying power as that of their Astronomical Eye-piece, and see for themselves. The small Star which accompanies the Pole Star is one of the best Objects for ascertaining the relative power of Glasses for shewing faint points of Light—and is most convenient—as the Telescope requires scarcely any motion to keep the Object in the centre of the field of view, even when the very highest magnifier is applied. The Belts and Division in Saturn's Ring are also excellent criterions of light and distinctness.

I have too much respect for Science and for myself, to assert any thing which I do not believe from experiments made by my own eye, to be the very Truth :—or to give my "*imprimatur*" to any thing that others have asserted, without a complete conviction of their having given a perfectly correct report.

"Too much has hitherto been taken for granted in Optics: every natural philosopher is ready enough to allow the necessity of making experiments, and tracing out the steps of nature; why this method should not be more pursued in the Art of Seeing does not appear. Theories are only to be used when proper data are assigned; but the data are to be carefully re-examined, when new improvements may widely alter the result of former experiments."—Sir W. Herschel, *in Phil. Trans. for* 1782.

In a *Concave Eye-glass*, only that part of the field is distinct, which is visible through the centre of the Eye-glass—if an object is viewed by looking through the sides of the Concave, it may certainly be seen after it has passed out of the field seen by looking through the centre of it—but it will be seen distorted.

That, can only be considered the actual and useful field of view, the Margin of which, is as perfectly distinct as the Middle of the field, when the Telescope is adjusted at an object seen in the middle of the field.

The Distinct field in a *Concave* and *Convex* of the same focal length and the same diameter—appears to my Eye to be the same, and the Indistinct Margin the same—only the *Convex* has this convenient superiority, that you see the whole of the field at once without any motion of the Eye—you can see only a portion of it in the *Concave*.

To ascertain the relative properties of *Concaves* and *Convexes*, I requested Mr. Dollond to make me a *Concave* and a *Convex*, each of exactly 1-3d of an inch focus, and from the same plate of Glass—that I might apply the test of comparison in the fairest manner possible.

In the Year 1824, with these *Single Lenses*, and with an excellent Huygenian Eye-piece with two plano-Convex Lenses producing the same Power, I frequently observed *Saturn*—the result is, that I think that the Belts, and the Division in the Ring,

are rather sharpest and most vivid with the *Concave*—but that my Eye cannot look through it but a very little while without feeling strained and tired.

The single *Convex* is scarcely inferior to the *Concave* in brightness and distinctness, and is not near so fatiguing to the Eye.

With the *Huygenian* Eye-piece, composed of two plano-Convex lenses, I think that the features of the Planet are not quite so sharp and bright as with the single lenses—but the vision is infinitely easier to the Eye—and those Persons who have looked through the several Eye-tubes, who were not so well aware of the necessity of keeping the object exactly in the centre of the field, when the Single Lenses are used, and from not being in the habit of using a Telescope, were not expert enough to keep it there—one and all greatly preferred the compound Eye-piece—with which, all the appearances seen with the Single Lenses were also visible—but not quite so bright.

*A Single Eye-glass* especially to a Telescope of less than 7 feet focus, is attended with exactly the same evils as *a Single Object-glass* to an Opera-glass—and the following *Obs.* on the latter Instrument, will aptly illustrate the former.

"The Chromatic and spherical aberrations which produce those prismatic colours, and distortion of the vision in the Margin of the field of view,—which so exceedingly distress the Eye, and are *the*

*main Evil of Single Object-glasses,* are in a great measure corrected in *Double* Object-glasses, with which the Image of Objects appears more Distinct, in proportion as the order in which the Rays proceed is better preserved.

" *The Grand superiority of the Double* or as it is commonly called the *Achromatic Object-glass,* consists in the field of view being almost quite as distinct at the margin, as it is in the middle, and thus, Vision is made easy to the Eye, with a considerable Magnifying power.

" The Eye, is sadly distressed and puzzled, how, to adjust itself with a Single Object-glass, when it magnifies more than three times—(especially if its focus is less than 5½ inches and its diameter more than 1¼), which then becomes indistinct, except just in the very centre of the Field. I think that *in the very Centre of the field* of a Single Object-glass, the vision is quite as vivid, if not more so than it is in a Double Object-glass—but as only just the very middle of the field is distinct, looking through it soon becomes much more fatiguing to the Eye, than with a Double Object-glass."—See page 93 of the Economy of the Eyes, Part I.

Dr. Herschel, in one of his observations, speaks of the decided superiority of *the single eye-glass,* when applied to his Newtonian. " I have tried both the single and double eye-glass of equal powers[4], and have always found that the single eye-

glass had much the superiority in point of light and distinctness. With the *double* eye-glass—and my 7 feet Newtonian, which has an aperture of 6$\frac{3}{10}$ inches, I could not see the belts of *Saturn*, which I very plainly saw with the *single* one: I would, however, except all those cases, where a large field is absolutely necessary, and where power, joined to distinctness, is not the sole object of view."—*Phil. Trans.* vol. lxxii. p. 95.—See Dr. H.'s Paper on the Parallel of the Fixed Stars—in the Chapter on DOUBLE STARS.

This account of Dr. H. respecting the extreme difference of the distinctness and light of Double and Single Eye-pieces, must have arisen partly, from the Double Eye-pieces which he used having been badly constructed, or the Glasses in them being imperfect; for, according to Dr. H.'s calculation of the Light transmitted by a Single and a Double Eye-glass;—the former is to the latter as 42 is to 40.—See his Paper on Penetrating into Space, in the Chapter on *Illuminating Power*.

So small a diminution of Light as only a twentieth part, could not be the sole cause for the great variation of vision which Dr. H. has recorded that he found between Single and Double Eye-glasses;—although a Good and highly educated and experienced Eye can discern much less variation, in the appearance and brightness of objects, than persons who are not practically acquainted with this subject may imagine.

I have observed, in the Chapter on "*Choosing Telescopes*," &c. that "a difference of 5 or 10 in the magnifying power will sometimes, on some objects—give quite a different Character to a Glass," and Mr. TULLEY states, in his Letter (see Chapter on *Cassegranian Telescopes*), that "on comparing a Gregorian and a Cassegranian Telescope, each of 7 inches aperture — at a very little *after sunset*, he could then plainly perceive a difference between a power of 77 and 82 — whichever Telescope had the power of 77, compared with the other at 82, was very visibly the lightest."

A Good Achromatic of $2\frac{3}{4}$, or a Gregorian Telescope of 5 inches aperture (neither of which are near so light as the 7 feet Reflector of $6\frac{3}{10}$ inches aperture, which was the size of the Telescope Dr. H. here alludes to), when the planet is in a favourable position and near the meridian, will shew *the Belt of Saturn*, with a Double Eye-glass magnifying 100 times: and, on Dec. 16, 1824, at half-past nine, when the planet was close to the meridian, I saw the Belt in my 7 feet Newtonian which has a Metal of $6\frac{3}{10}$ inches, and was made by Sir Wm. Herschel, with Huygenian Eye-tubes, magnifying from 80 to 240 times. — See Chapter on Saturn.

In *a Single Eye-glass*, especially if less than half an inch focus, whether Concave or Convex, the field of view is very small, and is distinct only in the very centre of it — so that in a Telescope of 5 feet focus which magnifies more than 100 times—it must be kept in

almost constant motion to keep a Planet in the centre of it.

Saturn or Jupiter so very nearly fills all the distinct part of the field of a Single Eye-glass, that we cannot see the whole of them distinctly for more than two or three seconds without moving the Telescope:—now, it is impossible to examine any object distinctly when it is in motion, and therefore, it is of great importance that the field of view be as large, and as uniformly distinct, as possible.

To my Eye, *Saturn* certainly appears sharper and brighter with a Single Concave or Convex Eye-glass—than I have seen it with any Compound Eye-piece,—composed of two or more lenses: but I have not found this to be the opinion of persons unused to observe, which I suppose is because the Single Eye-glass is Distinct only just in the centre of the Field, and the difficulty of keeping the object there is so great to those who are unaccustomed to manage Telescopes, that I have found them invariably complain, that the Vision with the Single was less Distinct than with the Double Eye-glass.

See other Observations on the comparative light of various Eye-glasses, &c. in the last page of my Chapter on *Diagonal Eye-pieces,* and on *Illuminating Power.*

To conclude—the difference in brightness, &c., is so small,—the advantage of the increased and uniformly distinct field of view is so great, and the

Vision is so much more easy to the sight, that, especially for Telescopes of less than 7 feet focus, (excepting where very minute objects, such as faint double Stars, are to be examined, and the utmost distinctness of the central point is of more consequence than extent of field,) my Eye always asks me to use the usual *Compound Eye-pieces* — these require care in constructing of proper proportion, and careful exactness in putting together.

The odds in difficulty of construction against the Compound Eye-piece are, Two additional surfaces to grind and to polish, *i. e.* the imperfections of another Lens — and the centring of them perfectly true to each other — however, these difficulties are easily surmounted by a careful Optician, and thus the Huygenian Eye-tube is undoubtedly the most desirable.

" The aberration from the figure, where Two Eye-glasses are rightly proportioned, is but a fourth of what it must unavoidably be where the whole is performed by a Single Eye-glass." — See Mr. Dollond's *Letter to* Mr. Short *in the Phil. Trans. for* 1753. And especially for Planets, and for Telescopes under 7 feet focus; because, when a single lens is shorter than half an inch focus, the aberration of Sphericity becomes extremely inconvenient for *Planetary* Observations. — *Stars* occupy so much smaller a portion of the Field of View, that for them it is of less importance.

## CHAPTER VI.

### REFLECTORS.

#### REFLECTING TELESCOPES.

The invention of the *Reflecting Telescope* may be considered the epoch when Optical and Astronomical pursuits began to become general:—the unwieldy length of *Refracting Telescopes,* adapted to any important purpose, rendered them so extremely inconvenient, that it required the utmost dexterity to use them, as it is necessary to increase their length in no less a proportion than the duplicate of their magnifying power; so that, in order to magnify twice as much with the same light and distinctness, the Telescope required to be lengthened four times, and to magnify thrice as much, i. e. nine times the length.

This unwieldiness of the *Refracting Telescopes* possessing the needful degree of Magnifying power, caused the attention of Astronomers and Opticians, &c. to be directed to the construction of *Reflectors;* and, early in 1672, Sir Isaac Newton completed his two small Reflecting Telescopes, which were but *Six inches long,* and were held in the hand for viewing objects, but in power were equal to a *Six Feet*

*Refractor.*—See the Account of Sir I. N.'s Telescope in the *Appendix.*

For the following Tables of the proportions of GREGORIAN and NEWTONIAN Reflecting Telescopes, I am indebted to page 39 of the Appendix to the *Nautical Almanack* of 1787, which now being out of print and become scarce, I have copied here, from the same motives Dr. Maskelyne inserted them in his book.

'*TABLE of the Apertures, Powers, and Prices of Reflecting Telescopes, constructed in the Gregorian form, by the late ingenious Mr.* JAMES SHORT*.

| Number. | Focal length in inches. | Diameter of Aperture in inches. | Magnifying-Powers. | Prices. Guin. |
|---|---|---|---|---|
| 1 | 3 | 1,1 | 1 Power of ——— 18 Times | 3 |
| 2 | 4½ | 1,3 | 1 —— ——— 25 —— | 4 |
| 3 | 7 | 1,9 | 1 —— ——— 40 —— | 6 |
| 4 | 9½ | 2,5 | 2 —— — 40 & 60 —— | 8 |
| 5 } | 12 | 3,0 | 2 —— — 55 & 85 —— | 10 |
| 6 } | 12 | 3,0 | 4 —— 35, 55, 85, & 110 —— | 14 |
| 7 | 18 | 3,8 | 4 —— 55, 95, 130, & 200 —— | 20 |
| 8 | 24 | 4,5 | 4 —— 90, 150, 230, & 300 —— | 35 |
| 9 | 36 | 6,3 | 4 ——100, 200, 300, & 400 —— | 75 |
| 10 | 48 | 7,6 | 4 ——120, 260, 380, & 500 —— | 100 |
| 11 | 72 | 12,2 | 4 ——200, 400, 600, & 800 —— | 300 |
| 12 | 144 | 18,0 | 4 ——300, 600, 900, & 1200 —— | 800 |

* Mr. *Short* charged higher Prices in 1768 than Opticians do now; although the price of labour and every article required in the

Mr. Short, in the above table, *always* greatly *over-rated* the highest power of his telescopes. By *experiment* they were found to magnify much less than expressed in his paper.

"To this circumstance alone," says the Editor of the Article *Speculum*, in vol. xxxii. Part II. of Dr. Rees's New Cyclopædia, "we are assured by *an Ingenious and Candid Optician*, it is to be ascribed,

construction of a Telescope is now much dearer—but *Short* had no competitor, and he spared neither trouble nor expense to make his Telescopes perfect—and then put such a price upon them as properly repaid him — and purchasers were content — because they were convinced that they received from him as perfect an Instrument as Art could produce.

Mr. Herbert,

Bought of James Short.

| | | £ | s. | d. |
|---|---|---|---|---|
| 1767. April 13. | To an Equatorial Telescope 18 inches Focal Length, the Aperture as large as one of 2 feet, | £115 | 10 | 0 |
| | With Achromatic Object-glass and Michrometer of 30 feet Focal Length | 26 | 5 | 0 |
| | To a Common Stand for the Telescope | 8 | 8 | 0 |
| | To an Helioscope - - - | 3 | 13 | 6 |
| | | £153 | 16 | 6 |

London, 13th April, 1767, Received of Mr. Herbert the Above Sum in full of all Demands.

Ja. Short.

N.B. The above was given me in May 1824, by Mr. Rubergall, Optician, in Coventry Street, in whose possession I saw the original.

that '*All following Opticians*' have been obliged, by way of satisfying the expectations of their Customers, to *over*-rate the highest power of their Telescopes, in order to obtain a price, adequate to their respective values."

Who "*the Ingenious and Candid Optician*" is, or who the Author of the article quoted is, I do not, nor do not wish to know—Who "*the Following Opticians*" are, it would, however, be very desirable to know, because no one would willingly enter the Shop of Tradesmen who practise imposition by system! but why should they over-rate their higher powers?—An Eye-tube, or a small Speculum, which magnifies 300, costs them very little more trouble than one that magnifies 200 times!!!

The present work, it is hoped, will completely dissipate all these delusions about monstrous Magnifying Powers, which have so long obfuscated the Operations of Opticians, and the amusements of Telescope fanciers.—See Chapter on "*Illuminating Power*," "*Magnifying Power*," &c.

Mr. Short finished two or three telescopes of the *Gregorian* form, of eighteen inches focus, with 4·5 inches aperture, and power 170.

He also made *One* telescope, of the *Cassegrain* form, of twenty-four inches focus, with six inches aperture, and power 355. But it was very indistinct with that power. The greatest magnifier it bore, with sufficient distinctness, was 231 times.

For want of Illuminating power, no Reflecting Telescope of 6 Inches aperture, or indeed of any larger aperture, will appear so distinct, when turned to a Planet, with 355 as with 231.—See Obs. on the 7 feet Newtonian. This telescope is well known in the optical world by the name of "*Short's Dumpy,*" and was originally made for the Honourable Topham Beauclerc, at whose sale it was purchased by the late Mr. Aubert, who pointed it out to me, in his observatory, as a very curious and unique instrument. This Instrument, Mr. Tulley assured me, is still in high preservation, and in the possession of Mr. Allen, of Plough Court, Lombard Street.

The *Cassegrain* differs from the *Gregorian* by the small speculum being convex.

*TABLE of Apertures, Powers, &c. of Telescopes of the NEWTONIAN construction.*

| Focal Dist. of concave metal. | Aperture of concave metal. | Sir Isaac Newton's numbers. | Focal Distance of Single eye-glass. | Magnifying Power. |
|---|---|---|---|---|
| *Feet* | *Inch Dec.* | | *Inch Dec.* | |
| ½ | 0,86 | 100 | 0,167 | 36 |
| 1 | 1,44 | 168 | 0,199 | 60 |
| 2 | 2,45 | 283 | 0,236 | 102 |
| 3 | 3,31 | 383 | 0,261 | 138 |
| 4 | 4,10 | 476 | 0,281 | 171 |
| 5 | 4,85 | 562 | 0,297 | 202 |
| 6 | 5,57 | 645 | 0,311 | 232 |
| 7 | 6,24 | | 0,323 | 260 |
| 8 | 6,89 | 800 | 0,334 | 287 |
| 9 | 7,54 | | 0,344 | 314 |
| 10 | 8,16 | 946 | 0,353 | 340 |
| 11 | 8,76 | | 0,362 | 365 |
| 12 | 9,36 | 1084 | 0,367 | 390 |
| 13 | 9,94 | | 0,377 | 414 |
| 14 | 10,49 | | 0,384 | 437 |
| 15 | 11,04 | | 0,391 | 460 |
| 16 | 11,59 | 1345 | 0,397 | 483 |
| 17 | 12,14 | | 0,403 | 506 |
| 18 | 12,67 | | 0,409 | 528 |
| 19 | 13,20 | | 0,414 | 550 |
| 20 | 13,71 | 1591 | 0,420 | 571 |
| 21 | 14,23 | | 0,425 | 593 |
| 22 | 14,73 | | 0,430 | 614 |
| 23 | 15,21 | | 0,435 | 635 |
| 24 | 15,73 | 1824 | 0,439 | 656 |

Dr. Maskelyne observes, that as Telescopes of Sir Isaac Newton's construction are now found (particu-

larly by the late exquisite observations of Mr. Herschel,) to perform most excellently in the minuciæ of Astronomy, especially if *Small-apertures, and Long foci* are made use of, I have added the foregoing table, chiefly taken from Dr. Smith's *Optics*, vol. i. p. 148. I have also annexed to it Sir Isaac Newton's numbers, by means of which the apertures and powers of Reflecting telescopes, may be easily computed.—See Appendix to Gregory's *Optics*, p. 229; or *Phil. Trans.* No. 81.

Dr. Smith, in the preceding Table, reckons that to obtain Double the Degree of Magnifying power you must have Quadruple the degree of Illuminating power—that is, to the Speculum of 6¼ inches Aperture he sets down a Magnifying power of 260—to the Speculum of 12 inches a Magnifying power of 506.

It may be necessary to mention, that the preceding table was constructed by using the dimensions of the middle aperture and power of Mr. Hadley's excellent Newtonian telescope as a standard; viz. focal distance of great mirror 62½ inches—aperture of the object-metal five inches, and power 208 times.

"Mr. Herschel chiefly makes use of a Newtonian reflector, the focal distance of whose great mirror is 7 feet, its aperture 6.25 inches, and powers 227 and 460 times, though sometimes he uses a power of 6450 for the fixed Stars."

"Note: If the metals of a Newtonian telescope are

worked as exquisitely as those in Mr. Herschel's seven feet reflector, the highest power that such a telescope should bear, with perfect distinctness, will be given by multiplying the diameter of the great speculum by 74*; and the focal distance of the single eye-glass may be found by dividing the focal distance of the great mirror by the magnifying power. Thus $6{,}25 \times 74 = 462$, the magnifying power; and $\frac{7 \times 12}{462} = 0{,}182$ of an inch, the focal distance of the single eye-glass required."

* This calculation must allude to the Power which it will bear for observing *Stars*.—Eye has never seen a Newtonian, or any Reflecting, or indeed any Achromatic Telescope, that would, for *Planetary* observations, bear, with any advantage to Vision, a higher magnifier than is given by reducing the diameter of the Large Metal into Tenths of Inches, and multiplying that sum by 3 or 4 at the utmost, which latter, requires every circumstance to be perfectly favourable.—For observing *Double Stars* I have occasionally employed a magnifier, that is given by multiplying the diameter by 10 and by 20—but very rarely with any advantage beyond 6 or 8. These computations will be found to coincide very nearly to the Numbers given to a 7 feet Newtonian of 6 3-tenths aperture in the preceding Table.

Dr. Smith's Table gives 260 for the Magnifying Power of a Newtonian with an aperture of $6\frac{1}{4}$ inches. Mr. Hadley's Newtonian of 5 feet focus and 6 inches aperture magnified 208 times.—See the Appendix.

With my Herschel 7 feet, of 6 3-tenths aperture, for looking at Saturn, I like an Huygenian Eye-piece magnifying about 213

Notwithstanding this high authority for making Newtonian telescopes of such extremely long foci, I am far from being convinced it is absolutely necessary that they need be made quite so long as 14 diameters of their object speculum, for any other reason, save the advantage arising from the use of Eye-glasses of longer foci, which is a very great advantage, because the aberration of sphericity is in them so much diminished:—we can get almost all the Magnifying Power which is wanted for Planetary observations with a single Convex lens of half an inch or a third of an inch focus with a 7 feet Newtonian.—See *Obs.* on Single Eye-glasses in Chapter V. on *Galilean Telescopes*.

The Vision of a Gregorian Telescope is as bright, and quite as distinct with a Speculum whose focal length is 6 times,—aye of only 4 times or even 3 times the diameter of its large Metal, as it is of any longer focus—and it must be as easy to produce the artificial curve required in telescopes of the Newtonian as it is in those of the Gregorian construction.

The curve which is best adapted to a Gregorian, one would suppose would be best for a Newtonian Speculum—but Opticians assure me that this is not

times—and not higher then 240. Sir Wm. H. used with such a Telescope a single convex which magnified 287 with my Gregorian Reflector of 9 inches Aperture—this Planet is seen best with 200 or 250.—W. K.

the fact, and that a Large Speculum which affords excellent vision with a *Plane* Small metal—is indifferent with a *Concave* one—and that which acts well with a *Concave* will not do so well with a *Convex*.—(See the end of Chapter IX. on *Cassegranians*.)

It costs only a few pounds to have a Plane small Speculum, &c. put to a Gregorian Telescope, and it gives an opportunity of trying many amusing experiments.

One of our best Practical Opticians, the celebrated *Short*, saw no necessity for Newtonians being so long;—the focal length of that which he made for the Royal Observatory at Greenwich, is only 8 diameters of its aperture; i. e. it is Six feet focus, and Nine inches and a quarter in diameter.

This is a manageable Machine, long enough to apply as great a Magnifier, and large enough to reflect as bright an image as is of any use to the Eye.

The Proportion fixed by those Experienced Makers of Reflectors Messrs. TULLEY, is one Inch of Aperture to one foot of Focal length. They have assured me that they cannot make them shorter, without the Instrument being much less perfect.

Northampton, May 1st, 1822.

DEAR SIR,

AFTER many trials to shorten the Newtonian Telescope below 12 times the diameter of the Object Speculum, I am now convinced, that

large Newtonians cannot be made to do their duty perfectly, unless they are at least 12 times the length of the diameter of the large Metal: in that case, they are certainly superior to any other Telescope.

Like many persons, I was for a long time incredulous as to the necessity of *Long Foci*, but experience has fully convinced me of it. My 7 Inch metal of 7 feet focus will always beat my 9 Inch metals of that length.

I cannot see η *Coronæ*, which Mr. Mosely informed me that he has seen in the most distinct manner with the 7 feet Newtonian of 7 Inches Aperture with 560 which you made for him:— my 12 inch Aperture blends the two stars together, and they appear as one ill-defined spot of light— they appear the same in my telescope of 9 inches Aperture; and for no other reason but that it is of only 7 feet focus.

Mr. M. observes that it is impossible to see any of the minute Double Stars distinctly defined, unless the weather is Warm, Clear, and Calm.

I am, Dear Sir,
Yours truly,
R. Comfield.

To Mr. Tulley, Optician, Islington.

The above was communicated to me by Mr. Tulley— who informed me that Mr. Comfield had had a great

deal of experience both in making and using reflecting Telescopes, and that his opinions are quite correct.—See more on this subject in Mr. TULLEY's *Letter*, on 7 Feet *Newtonians*.

In Newtonian Telescopes, Dr. HERSCHEL says, in his Paper on the Quintuple Belt of Saturn in the *Phil. Trans.* vol. lxxxiv., that "*the maximum* of distinctness, is much easier obtained, in a speculum of Six inches and a quarter aperture, than it can be in larger ones." This was the size of the Telescope he made his Astronomical catalogues with, and in his hands it has worked wonders.

Dr. H. observes, that his 7 feet Newtonian, which has an Aperture $6\frac{3}{10}$ths inches, "has sufficient light with a Single eye-glass, of $\frac{3}{10}$ths of an inch focus, which gives it a Magnifying power of 287, to shew the Belts and Double Ring of *Saturn* completely well*." What can we wish for more? *How many, have expended large sums of money on Telescopes, without having ever seen these All-repaying Sights.*

If I was now to order a Telescope for Astronomical

* In page 51 of vol. lxxxiv. of the *Phil. Trans. for* 1794, Dr. H. says, "my 7 feet Reflector bears an Eye-glass of 3-tenths of an inch focal length.

"My object Specula are generally from 84 to 88 inches focus, and, therefore, give a power from 280 to 293. The favourite one gave 287."—(See Chapter XIX. on "*Saturn*" and Chapter XVII. on "*Illuminating Power*."

purposes for my own use—I would have a Newtonian of not less than 7 feet focus, or a Gregorian of 3 feet focus and 7 or 9 Inches diameter.—See *Obs.* on "*Newtonian* and *Gregorian Telescopes*"—and on "*Saturn*," and Mr. COMFIELD's *Letter* in p. 77.

In Dr. H.'s account of his Lamp Micrometer, in *Phil. Trans.* for 1782, he says, "the power of 460 my telescope bears so well on the fixed Stars, that for near a twelvemonth past I have hardly used any other."

In page 5 of the *Phil. Trans.* for 1790, the Dr. informs us that "with 410 his 7 feet reflector had hardly light enough for Saturn."

The following are interesting facts about LARGE TELESCOPES:—

"The Strong light of the 20 feet Reflector was too great a fatigue to the Eye, which cannot bear to look at a very luminous object for a long time together; for which reason (in observing Saturn) I chiefly used my 7 feet Reflector."—See *Phil. Trans.* for 1794—and Dr. MASKELYNE's *Obs.* in page 42 of the Appendix to the *Nautical Almanack for* 1787, and Dr. Herschel's *Obs.* on $\gamma$ *Leonis.*—See *Phil. Trans.* vol. lxxv. p. 48, and Chapter XX. of this work. Sir W. H. observes, that "with the 20 feet Reflector and Power 350, $\gamma$ *Leonis* is too bright an Object to be quite distinct." The Aperture of his 20 feet Reflector I believe was about 18 inches—and of the 10 feet, 9 inches.

QUERY: Can the *acmè* of perfection, be obtained in metals larger* than 6 inches in diameter? Mr. TULLEY and Mr. WATSON have candidly declared to me, they would rather not undertake to make Specula larger than 9 inches in diameter, if required to engage that they would *shew Stars round and neatly, like Silver spangles on a bit of Black cloth.*—See Sir W. H. *Obs.* and the diagram of *Castor* in the frontispiece to this work. "They should give the apparent diameter of Stars perfectly round and well defined, with a deep black division between them"—and unless they will bear this severe ordeal, their figure cannot be depended on for exhibiting any object with that perfection, which is the *sine quâ non* of Astronomical Telescopes. To define DOUBLE STARS distinctly and shew the Division in Saturn's Ring, are undoubtedly the best tests of the perfection of the Instrument and of the perfection of its Adjustment, for observing every other object.

It must ever be present in our Recollection, that the Quality of the Light, is as important as the Quantity of it—increasing the Apertures of our Telescopes, unless they are in every part equally perfect—will be of no use.—See Mr. COMFIELD's *Letter*, at page 77.

To make a Reflector of 7 inches Aperture shew Stars as Sir W. H. has delineated the diagram of *Castor*, (see Frontispiece,) is a difficult task for the best

workman — and is a task which perhaps will very seldom be accomplished with a Speculum beyond that diameter.

Have a light wooden Cap to put on the end of your Telescope which will contract the Aperture half an inch, and fit into this two others of Pasteboard which will each contract it half an inch more — you will find them very convenient in comparing the Illuminating power of Telescopes and for observing the Sun — Moon — and Double Stars. — (*See Chapter XX. on Double Stars.*)

The dimensions of Instruments are limited—Optical Art is, as I have before said, circumscribed, by certain impediments which prevent the application of a higher power than 400 times.

This is so true, — that, until these Obstacles are removed, we need not hunt after monstrous Telescopes, unless it be in the true hobbyhorsical spirit, *for the sake of the Pleasure arising from the Trouble of using them.*

Immense TELESCOPES, *are only about as useful,— as the* Enormous SPECTACLES *which are suspended over the doors of Opticians.*

Those who are acquainted with the laws of Mechanics know, that all the productions of Art are circumscribed by Nature, and governed by certain laws and proportions.—If these are overstepped, to render one part of a Machine more powerful, another part will in proportion become less perfect; so that

when this line of perfection is broken, as much as is gained one way is commonly lost another, or the good of the whole is sacrificed for certain parts.

> "Est modus in rebus, sunt certi denique fines,
> "Quos ultra citraque nequit consistere rectum."

According to this rule, I have endeavoured to prove that Optical instruments and their Magnifying powers have their proper limits, — as well as every other thing which is made by the hands of Man.

I do not believe that Art has yet produced a Reflector beyond 7 inches, or an Achromatic beyond $3\frac{8}{10}$ths in diameter, of which the Defining power has proved quite perfect when tried on a fixed Star. I have no doubt that this was the reason why Sir W. H. chose the 7 feet Newtonian for forming his Catalogue of Double Stars in preference to any of his larger Instruments — of which at that time he had several of 10 and 12 inches in diameter. — See *Phil. Trans.*

THE LENGTHS—APERTURES—ILLUMINATING—AND MAGNIFYING POWERS, AND PRICES, OF GREGORIAN REFLECTING TELESCOPES, AS NOW MADE BY MESSRS. TULLEY AND SONS, TELESCOPE MANUFACTURERS, TERRIT'S COURT, UPPER STREET, ISLINGTON.

| Name they are known by. | | Diameter of Aperture. | Illuminating Power. | Usual Magnifying Powers. | Price. | |
|---|---|---|---|---|---|---|
| *Feet* | *Inches* | *Inches* | | | L. | s. |
| 1 | 0 | 2½ | 52 | 50 | 7 | 7 |
| 1 | 6 | 3 | 90 | 50<br>100 | 12 | 12 |
| 2 | 0 | 4 | 160 | 60·90<br>120·180 | 16 | 16 |
| 3 | 0 | 5 | 250 | 60·90<br>120·180 | 42 | 0 |
| 4 | 0 | 7 | 490 | 77·130<br>200·350 | 105 | 0 |
| 5 | 6 | 9 | 810 | 90·130<br>200·350 | 210 | 0 |

OF THE NEWTONIAN CONSTRUCTION.

| | | | | | |
|---|---|---|---|---|---|
| Herschel, 7 feet.<br>7<br>Improved<br>7 | $6\frac{3}{10}$<br>7 | 396<br>490 | 50 to 1000 | 100<br>126 | 0<br>0 |
| 10 | 10 | 1000 | 50 to 1000 | 315 | 0 |

# ACHROMATIC TELESCOPES

MANUFACTURED BY

## CHARLES TULLEY AND SONS.

---

| | £. | s. | d. |
|---|---|---|---|
| PORTABLE Telescopes, 1 foot when drawn out, and 5 inches when shut up, Object-Glass 1¼ inch diameter | 1 | 15 | 0 |
| Ditto, 1½ foot when drawn out, and 7 inches when shut up, Object-Glass 1½ inch diameter | 2 | 12 | 6 |
| Ditto, 2 feet when drawn out, and 9 inches when shut up, Object-Glass 1¾ inch diameter | 3 | 13 | 6 |
| Ditto, 2½ feet when drawn out, and 10 inches when shut up, Object-Glass 2 inches diameter | 5 | 5 | 0 |
| Ditto, 3 feet when drawn out, and 10 inches when shut up, Object-Glass 2¼ inches aperture | 6 | 6 | 0 |
| Ditto, 4 feet when drawn out, and 14 inches when shut up, Object-Glass 2¾ inches aperture | 12 | 12 | 0 |
| 1½ foot Telescopes, to be used at Sea, commonly called Navy Telescopes, Mahogany Tube, with one Brass Draw for Eye-piece | 2 | 0 | 0 |
| 2 feet ditto | 2 | 12 | 6 |
| 2½ feet ditto | 4 | 0 | 0 |
| 3 feet ditto | 4 | 14 | 6 |
| 4 feet ditto | 7 | 7 | 0 |
| Night Telescopes to be used at Sea, in Mahogany Tubes, mounted with Brass, 2 feet long | 3 | 3 | 0 |
| 2½ feet Telescopes, Brass mounted, on plain Pillar and Claw Stand, with 1 Eye-piece for Astronomical Purposes, and 1 for Land Objects, to vary the magnifying Power, packed in a Mahogany Box | 10 | 10 | 0 |

| | £. | s. | d. |
|---|---|---|---|
| 2½ feet Telescopes, Brass mounted, on Pillar and Claw Stand, with elevating Rack, 1 Eye-piece for Astronomical Purposes, and 1 for Land Objects, to vary the magnifying Power, packed in a Mahogany Box .. | 12 | 12 | 0 |
| 3½ feet ditto, 2¾ inches aperture, with plain Pillar and Claw Stand, 2 Eye-pieces for Astronomical Purposes, and 1 for Day Objects, to vary the magnifying Power, packed in a Mahogany Box ...... | 21 | 0 | 0 |
| Ditto, ditto, with elevating Rack and Achromatic Finder, 2 Eye-pieces for Astronomical Purposes, and 1 for Day Objects, to vary the magnifying Power, packed in a Mahogany Box ............ | 26 | 5 | 0 |
| 3½ feet Telescopes, 3¼ inches aperture, with Vertical and Horizontal Rack-work Motions, Achromatic Finder, 3 Eye-pieces for Astronomical Purposes, and 1 for Day Objects, to vary the magnifying Power, packed in a Mahogany Box ............ | 42 | 0 | 0 |
| Ditto, ditto, 3¾ inches diameter, mounted as above . | 68 | 5 | 0 |
| Ditto, ditto, with Universal Equatorial instead of Pillar and Claw Stand ...................... | 84 | 0 | 0 |
| 5 feet ditto, 3¾ inches aperture, on a Universal Equatorial Stand, with Achromatic Finder, 4 Eye-pieces for Astronomical Purposes, and 1 for Day Objects, to vary the magnifying Power, packed in a Mahogany Box, from 100 Guineas to .......... | 157 | 10 | 0 |
| 7 feet ditto, 5 inches aperture, on a newly improved Universal Equatorial Stand, 6 Eye-pieces for Astronomical Purposes, and 1 for Day Objects, to vary the magnifying Power, with Achromatic Finder, and Troughton's Micrometer .................. | 275 | 0 | 0 |

The foregoing Table gives the proportions of which Reflecting Telescopes are usually made, but if the Purchaser is willing to pay an extra price for the additional trouble in working the Metals of a shorter focus, he may have a Gregorian Telescope not exceeding four inches Aperture, of any length, so that it be not shorter than three diameters of its aperture; but there is no use in making telescopes of extremely short focus, if their aperture is larger than 2 inches: the only advantage of making those so short is to render them more easily portable—a Tube of 3 inches diameter if only 8 inches in length is not a portable thing from its Diameter.—See *Obs.* on DUMPIES in Chapter XVII. *on Illuminating Power*.

The Reader will see by the above Table, and that of Mr. SHORT'S (p. 68), that the usual proportion of the Apertures of *Gregorian Telescopes*, to their Focal Lengths is as *One* to *Six*; which is quite Short enough, and you have a much greater chance of having a fine Instrument by having it of the Dimensions usually made, because you may have the choice of several Metals.

It has been said even by practical Opticians, that *Short Gregorian Telescopes* give a neater image of a Star, than those of the usual length — is it not contrary to all Theory, that deep curves should have less aberration than shallow ones? I venture to ascribe the usual superiority of Short Gregorians to another

cause than their Shortness. These Dumpy Telescopes are usually bespoke by Amateurs, who are willing to pay a good Price for a good Instrument, therefore the maker sets to cheerfully, determined to do his best, having the double inducement of being well paid for his labour, and of its being duly estimated by being in the hands of those who will properly appreciate it; he will have Credit for his good work as well as Profit.

As I have before observed, it is not near so difficult a task to make a Telescope that will shew Day objects and Planets tolerably well, as it is to produce one that will define a Star properly: — unless the Telescope is made on purpose for observing Celestial objects the requisite trouble is not taken to render it perfect for such purposes, if it was, the Instruments could not be sold at the cheap rate which common Telescopes are sold at: — I have put the reader into possession of the power of judging of the goodness of Telescopes, and it is just to those who make them, to candidly acquaint him that Opticians, like all other Artists, must be paid extra, if extraordinary excellence be required.

Were I to order a *Gregorian* or *Newtonian*, I would not have the former shorter than 4 diameters of its large Speculum, nor the latter shorter than 9: and when I ordered it, should say to the maker — if your Instrument does not define sharply, I will not have it any more than I would have a Razor that

would not shave sharply; if it does, I will willingly pay you for your extra trouble in making it: at the same time asking what sum would satisfy him.

If an Optician desires to make a perfect Instrument, He must make Two sets of Specula *:—this alone—can give him a fair chance of doing his best.

So easy it is to get a tolerably good figure, that will do pretty well for Day purposes—and so extremely difficult it is to obtain a figure that will perform perfectly well for Celestial purposes—that if the *Buyers* are unwilling to pay for the extra labour,—they ought not to be very much astonished,—if the *Sellers* are willing to stop, when the figure is tolerably good, rather than run the risk of destroying a week's work, by trying to make it a fine one.

Get one Metal as good as you can, then set to work at another, and when you are quite sure that you have made the second more perfect, try to mend the first: thus, by alternately working one after the other, you may at last obtain that "*ne plus ultra*" *of perfection*, which, to the most experienced and expert Optician, *is always accidental.*

Therefore, the Makers of Telescopes should keep to certain sizes—the fewer varieties of either Aperture or length, the better both for the Buyers and the Sellers, as the greater number of fine Instru-

* See Dr. HERSCHEL's account of his labours in Specula-making, in Chapter VIII. of this work.

ments may be picked out—and the less will be the expense of making Tools and the trouble of manufacturing Telescopes.—See Mr. S. Gray's Experiment to make Concave Specula of a Parabolic figure, in vol. xix. p. 787 of the *Phil. Trans. for* 1697—Dr. Gregory's Elements of Cat- and Di-Optrics, by Dr. Desaguliers, 8vo. 1735—and the Rev. S. Hardy's Translation of Sherffer on Dioptrics, 8vo. 1768.—See Directions for making Reflecting Telescopes by Mr. Mudge, vol. lxvii. of the *Phil. Trans.* p. 297—and Mr. J. Ramsden's Observations on Cassegrain Telescopes, in vol. lxix. p. 425.

The perfection of a *Speculum* consists in its *Figure*, its *Weight*, (its reflective power being in proportion to its specific gravity,) and its *Whiteness*.—See Martin's New Elements of Optics, 8vo. 1759.

*The Colour of the Metal* is very important; in a fine white metal we see the different colours of the Moons of Jupiter, &c. — which are not distinguishable in tarnished Metals and those of a yellow hue, or in Object-Glasses which are not perfectly Achromatic.

" *The Polishing of the Speculum*, is the most difficult part of the whole process; for every experienced workman knows to his vexation, that the most trifling error here will be sufficient to spoil the figure of his metal, and render all the preceding caution useless." — Mudge on Reflecting Telescopes in vol. vi. p. 317 of *Phil. Trans.*—and see the Rev. John Edwards and Dr. Maskelyne's Directions

for making and adjusting of Reflectors in the Appendix to the *Nautical Almanack for* 1787.

But the performance of the Telescope depends much more upon the *Figure* of the Metal, than upon the *Polish* of it—and the Workman has often infinitely more trouble to make a good-looking Speculum, than a good-acting one. To obtain both, is as rare, as it is to meet with a human Head of which you equally admire the outside and the inside. I do not assert this without having had experience that I am stating the Truth.

I have a favourite one foot Reflector made by Mr. Watson, which being a very perfect and portable Instrument formerly accompanied me as my travelling Telescope:—on my return home after a trip to the Sea Side, I found to my great concern that the Large Speculum was spotted all over as if it had caught the Small Pox: having then not had much experience in these things, I concluded that the Metal was quite spoiled, and had a New one made—however, on comparing the New Metal with the Old one, to my extreme astonishment I found my Old friend *the Small Pox Speculum* still shewed Objects decidedly brighter than the fair-faced New one did. This apparently unaccountable fact, is easily accounted for. The quantity of light lost by the spots on the old Speculum was more than compensated by the exquisite perfection of its defining power—the harmonious action of every part of the

old Speculum produced that brilliant vision which the less perfect figure of the new one failed to produce, notwithstanding its polish was more perfect.

On the 25th August, 1807, when the Duke of Richmond's Instruments were sold at Mr. Berge's, the Optician, in Piccadilly,—I saw the 7 feet Newtonian Reflector with a Speculum $6\frac{3}{10}$ths inches in diameter, and made by Dr. Herschel, and for which the Dr. had 210*l.*; in this Telescope, the Stars appeared as *very small points*, with scarcely any sensible diameter, without any rays, &c. from them. I took my *Beauclerc*, which has a triple Object-Glass of $3\frac{6}{10}$ths inches in diameter, to compare with it—the Reflector was *much* lighter and pleasanter vision—notwithstanding that *the Metal was very much tarnished*—this Newtonian was one of the finest telescopes I ever saw, and was purchased by Mr. Thoulden for 83*l.*

It is of the utmost consequence to the perfection of Reflecting Telescopes, that the Mirrors be placed truly parallel to each other, and that the centres of them, together with the centres of the Eye-glasses, be all in one direct line; viz. in the axis of the tube: unless this be very carefully attended to, the Instrument will appear indistinct and imperfect, especially when turned to a Star, even though the Mirrors have the most perfect figure and most perfect polish possible.

That truly excellent artist, Mr. JAMES SHORT, always took the greatest care to adjust* and centre the metals of his telescopes, which he termed "Marrying of them."

"Mr. Short used to proceed by first making his Large metal as nearly correct and parabolical as he could, and then, from a number of Small metals, to select, by trial, that which corrected the large one in the best manner."—Dr. REES's *New Encyclopædia*, vol. xxxv. Part I. Article *Telescope*, in which the Reader will find much information on that subject.

"You will perceive a sensible difference in the sharpness of the image under *different positions of the Great Speculum* with respect to the Little one, by turning round the great metal in its cell, and opposing different parts of it to different parts of the little metal, correcting by this means the error of one by the other. This attempt should be persevered in for some time, turning round the Great Speculum about $\frac{1}{16}$ at a time, and carefully observing the most distinct situation each time the Eye-piece is screwed on: when, by trying and turning the great Metal all round, the distinctest position is discovered, the upper part of the Metal should be marked with

* See particular directions *how to adjust a Reflecting Telescope*, in the Appendix to the *Nautical Almanack for* 1787.

a black stroke, that it may always be lodged in the cell in the same position. This is the method Mr. Short always used; and the caution is of so much consequence, that he thought it necessary to mention it very particularly in *his Printed directions for the use of the Instrument*. Mr. Short also frequently corrected the errors of the Great by the Little metal in another way. If the great speculum did not answer quite well in the telescope, he cured that defect sometimes by trying the effect of several metals successively, by this means correcting the errors of one by the other; for in several of his telescopes which have passed through my hands, when the sizes and powers have been the same, I have found that the great metals, though very distinct in their proper telescopes, yet have, when taken out and changed from one to the other, spoiled both telescopes, rendering them exceedingly indistinct, which could arise from no other circumstance. For this reason I suppose it was, that he kept ready finished, a great many large metals of the same focal length, so that, when he wanted to mount a telescope, he might from a great choice, be able to combine those metals which suited each other best. I am strongly inclined to believe this was the case, not only from the above observation, but because he shewed me himself a box of finished metals, in which I am sure there were a dozen and a half of the same

focal length."—Mr. J. MUDGE on Reflecting Telescopes, from the *Phil. Trans. for* 1777.

*If the Mirrors are perfectly well figured, and are truly centred and adjusted to their best position*, a fixed Star, when the Telescope is put out of focus, should appear, in Reflecting Telescopes, as a *round* luminous circle with a black spot exactly in its centre;—when the Telescope is adjusted to distinct vision, the Star will appear, (if the Telescope is excellent, and the state of the air favourable,) exactly *Round*, and totally free from all irradiations, or false rays and glare. When the Image becomes indistinct at points of the tube equally distant from the point of distinct vision as the Eye-tube is put in or out from its focal point, it is considered one of the best tests of a good Telescope.

No object is so proper *to determine the excellence and the adjustment of Telescopes*, as the Fixed Stars, as the least irregularity in the adjustment of the Metals in Reflecting telescopes, or of the Object-glass in Achromatics, is rendered by them exceedingly conspicuous by a false glare, and by their not appearing perfectly round.

To expedite the difficult business of adjustment, various substitutes for Stars have been contrived by which to adjust telescopes during the Daytime — but I have been assured by several candid practical Opticians that none are to be depended upon.

One of the most curious reflecting telescopes I have ever seen, is a DUMPY Cassegranian made by Mr. BUTT, of Bath. It is of eight inches aperture, and only sixteen inches focus. I saw *Geminorum* with it, very neatly defined as two points. The instrument was not then finished, and only one Eye-tube was glassed: with this it performed very well, and promised to be a fine Telescope.

I have a little *dumpy* Gregorian of only Two inches aperture and barely Four inches focus, made by Mr. Cuthbert, which shews *Jupiter* and *Saturn* beautifully sharp, and defines some Double Stars in the neatest manner, with a power of 130; the separation of the Two Stars of *Castor* is extremely distinct. — See *Obs.* thereon in Chapter XX. on *Double Stars.*

About 25 years ago I had some Reflecting Telescopes made for me by Mr. CARY, optician and mathematical instrument maker, in the Strand, one of which was a *Newtonian* of 7 feet focus, and the aperture Six and $\frac{3}{10}$ths inches; another a *Gregorian* of 7 inches Aperture and 27 inches focus.

I had also a *Newtonian* of 7 feet focus, with a Metal of seven inches, made by Mr. WATSON.

I had a Gregorian, made by Mr. TULLEY, of Territ's Court, Upper Street, Islington, of 7 inches aperture, and 27 inches focus.

The Instruments were got up on purpose for me,

at an unlimited expense, and from the acknowledged ability of the makers, there can be no doubt that all care was bestowed on them; and, they performed extremely well in the Daytime, and exhibited *Jupiter* and *Saturn* in a brilliant and beautiful manner;—their aperture being so large, they illuminated *Saturn*, especially the Belts and the Black list on the ring, as it was formerly called; or, as it is now called, the Division or space between the Rings, in a very satisfactory style. I think that the Vision with the Newtonians was easier than with the Gregorians; and most pleasant with a power of about 213. A lower power does not magnify enough; higher magnifiers do not afford sufficient light.

However, I could not always get all these Reflectors to perform so well as a fine Refractor, when turned to fixed Stars, which some of the Reflectors sometimes shewed with more or less of false light about them, when in the same five minutes I have seen them with my Achromatic, perfectly free from all accompaniments, round and sharply defined, like little Planets.

However, in justice to the Makers of these Instruments, I must here note, that they were not made expressly for examining *Double Stars*—which pursuit 30 years ago had hardly come into fashion: and unless a Telescope is ordered especially for that purpose it will very rarely well define those objects.—See Dr. HERSCHEL's paper "On the causes which

affect Mirrors so as to prevent their shewing Objects distinctly."

"It must be noticed, that few Specula or Object-glasses are so very perfect as not to be affected with some rays or inequalities, when high powers are used, and the object to be viewed is very minute."—Dr. HERSCHEL, in *Phil. Trans.* vol. lxxxviii. p. 69.

When a Telescope is pointed at a Star, the least Defect in the figure, or adjustment of the metals in a Reflector, or of the object-glass in an Achromatic, immediately stares in your Eye,—the Star not appearing round, but surrounded by false lights, radiating points, and little flitting luminous accompaniments.

They make their appearance in a Periwig,—instead of presenting themselves clean shaved,—or like round Silver Spangles on a bit of Black Cloth.

Sir William Herschel advises those who wish to examine the closer *Double Stars,* "to previously adjust the focus of their Glass with the utmost delicacy, on a Star known to be Single, of as nearly as possible the same Altitude, Magnitude, and Colour, as the Star which is to be examined, carefully examining the circumstances of the Star they adjust by, whether it be round, and well defined, or surrounded by little flitting appendages which keep playing about the image of the Star, varying in their appearance as it passes through the field, or remaining fixed to it uniformly the same."

These imperfections of the Object-Glass, or Object-metal, or Eye-piece, may be detected by unscrewing, or turning them about in their cells.

They have occasioned inexperienced star-gazers to make many discoveries of blazing Stars, Comets, &c.: the following is a specimen :—

" A few evenings since, a gentleman looking at the planet *Jupiter* through a telescope, observed a luminous appearance at a small distance below the planet, in shape approaching to the arc of a circle of about 90 degrees or more; the horns pointing to the horizon; the rim narrow and hair-like, something resembling the moon two or three days old, but of a very pale whitish colour: sometimes, however, much more vivid and brilliant. This appearance has no doubt attracted the attention of astronomers, as it still retains nearly the same position in the heavens."

The above was in the *Morning Post*, July 23, 1817. I sent the following to the Editor.

THE PLANET JUPITER.

*Mr. Editor*—The appearance of the planet *Jupiter*, noticed in your paper of the 25th inst., is nothing more than an optical delusion, arising from some defect in the telescope of the gentleman who observed it. If he turn his glass to any fixed star of the first magnitude, he will probably find the same

appendage to it as he has seen to *Jupiter*, which is occasioned by some defect in the figure or adjustment of the metals in reflecting telescopes, or of the object-glass in achromatics. Dirt upon the eye-glasses may produce the same effect.

I observed *Jupiter* last night with the celebrated achromatic of 46 inches focus, with a treble object-glass of 3¾ inches aperture, (which was originally made for *the Hon. Topham Beauclerc*,) which I purchased at the sale of the astronomical *Mr. Aubert*. With this well-known and perfect instrument, charged with a power of 150 times, there was nothing unusual in the form of the planet, which appeared well defined.

I am, &c.

July 25, 1817. W. K.

A difficult object to define in the Daytime, and perhaps the best test to try the distinctness and correctness of our Instruments, is *the Dial-plate of a Watch* when the sun shines upon it, placed about 100 feet from the glass, as is also a Weathercock, which has light all around it.—(See Chapter XVI. on *Comparing Telescopes*.)

In the Appendix to the *Nautical Almanack for* 1787, are "Directions for making the best composition for the metals of Reflecting Telescopes; and the method of Casting, Grinding, Polishing, and giving them the True Parabolic Figure, by the

Rev. JOHN EDWARDS, B.A.; published by order of the Commissioners of the Longitude."

In which Mr. Edwards observes, that "to produce an equal effect, the diameter of the aperture of a common Reflecting telescope must be to that of an Achromatic telescope as 8 to 5—but that by a careful experiment, he found that Mr. Edwards's metal, which was composed of

| | |
|---|---|
| Copper .............. | 32 parts |
| Tin ................ | 15 |
| Brass ................ | 1 |
| Silver ................ | 1 |
| Arsenic .............. | 1 |

of seventy-one mixtures, was by much the hardest, whitest, and most reflective."

"Mr. Edwards's metals shew a white Object perfectly white, and all objects of their natural colours, very different to common reflecting telescopes, which give a dingy appearance to objects which they shewed as bright as a Treble Object-glass Achromatic, both being put under equal circumstances of areas of the apertures of the Object-metal and Object-glass, and equal Magnifying powers."—See Chapter XVII. on *Illuminating Power*.

The following is an Extract from Mr. VARLEY's account of Lord STANHOPE's Telescope, in the *Journal of Arts* for January and February 1820, pp. 48 and 116.

"In order to have the Glass, of which his lenses were to be made, equally good, and of the same refractive power, he purchased a large plate, and had it cut into slips for that purpose; so that having once ascertained its refractive power, and carefully measured the radii of the tools in which it was to be ground, he could be sure of the foci of the various lenses which he intended to be made. He paid equal attention to the composition, casting, and working of his metals. For this purpose he procured a sufficient quantity of purified copper and tin; and for casting them his method was different, and much superior to that in common use: instead of melting the metal in common melting pots, and then pouring it into moulds made of wet sand and loam, he melted his metal in a vessel or pot made of cast iron, *a*, Plate V. fig. 4, with a pipe of the same material, *b*, inserted into a hole in the bottom, and rising a little above it, as at *c*, its lower end being well fitted into the cover, or upper part of the mould, *d*, which had a rebate, *e e*, to receive it; the mould, with its cover, pipe, and melting pot, being placed upon a large iron grate, upon which was built a fire-place, made of loose bricks not closely joined, in order that a sufficient quantity of air might be admitted, and large enough to receive a proper quantity of charcoal for melting the metal. The hole in the bottom of the melting pot, was stopped up by a plug or stopper, *b*, made of wrought iron, the lower end

being a little conical, and made to fit the hole of the pipe at *c*, and surmounted with the flanch *g*; this plug or stopper was made long enough to reach a few inches above a loose cover made to cover the top of the melting pot, which had a hole in the middle for this plug to pass easily through.

"As it is desirable to know when there is a sufficient quantity of melted metal, the following method will determine that near enough. There is always some scoria at the bottom, as well as some floating upon the melted metal, neither of which must be suffered to enter the mould: the first is prevented by the pipe *b*, standing up a little above the bottom, as shewn in the figure; the latter, by having more metal than will fill the mould; this may be known by first putting the plug into its place, and then putting in as much dry sand as will rise a little above the flanch, *g*, and then fill the mould with dry sand, which add to that already put in the melting pot, and notice the height which the two portions of sand occupy, and that will be a sufficient guide. Then pour out the sand, and put every thing in its place; put in a first quantity of metal, and put on the loose cover, after that nearly fill the fire-place with charcoal, upon that some charcoal already ignited, and then more charcoal to cover the whole. I ought to have said, that the bottom of the fire-place should have some loose pieces of bricks put in it to fill it nearly to the bottom of the melting pot, to prevent the

upper part of the mould becoming too hot, which it would otherwise do. And for that reason the fire should be lighted at the upper part first, which may be promoted by a pair of hand-bellows, and the metal will soon be melted, and more added until there is enough. When that is obtained, and the metal melted, it may be let into the mould by raising the plug a little, but not so much as to raise it quite out of the pipe: this is done best by having a pin, *h*, in the plug, a little above the loose cover, in order to apply a rod of iron as a lever, by which the plug may be raised until the metal is seen to run into the mould, and when that is full, the fire should be removed as quick as possible by removing the bricks of which the fire-place was built, and the whole to be left until all is cold. By this method I cast many metals for his lordship, which proved better than any which I have ever seen cast by any other means.

"The metal should be previously prepared and granulated in the following manner, and in the proportion of thirty-two parts of copper to fourteen of grain tin; the copper to be melted in a common melting pot in a wind furnace, and then the tin melted in an iron ladle, and poured into the melted copper; and after stirring it with an iron rod, the whole should be quickly poured into a vessel of cold water by a gentle stream, and it will be found granulated and made convenient for introducing

into the melting vessel. I could give sufficient reason for the whole of this process; but it will be enough to state, the metal will always prove good when so managed.

"The tin will mostly be found in too small a quantity in the above proportions; but as different sorts of copper require different proportions of tin, the proper quantity can only be known by making a trial, which is most conveniently done in the second melting, by taking a small quantity out of the melting vessel with an iron ladle, having an upright handle: half an ounce will be quite sufficient; when cold, grind it upon a plate of metal with a little fine emery, to discover whether it breaks up too much to bear grinding; afterwards break it, to judge of its strength and colour, which may be done in a few minutes: more tin may be added, if required, a little at a time, until it is brought to a proper state for working. By working, I mean grinding and polishing.

"Nothing that I have yet mentioned deserves the name of difficult, compared to the last operation of grinding and polishing; particularly in the working of *Flat metals*, such as the little metals for a Newtonian telescope.

"I have known one of the most experienced workmen bestow the labour of three weeks upon one of these, and, after all, he owned to me it was not flat; this metal was not more than two inches in its transverse diameter. But to obtain any thing perfectly

flat, or straight, or square, or round, or spherical, or any other figure, is not within the reach of Human Industry."

The late indefatigable and ingenious Earl of Stanhope had a plan for constructing a still more stupendous Optical Instrument than even the 40 feet Telescope of Sir Wm. Herschel. Mr. VARLEY informs us, in page 36 of No. 1, January 1820, of the London Journal of Arts and Sciences, that "his Lordship's vast design was no less than the construction of a Telescope of 384 feet in Length, with Reflectors 6 feet in Diameter.

"The observer may sit or stand in a warm room, and, without ever changing his position, observe more than one half of the horizon, the object appearing directly before him, however elevated it may be in the heavens; thus continuing in the easiest posture and without ever being exposed to the open air. No other telescope affords these very desirable advantages.

"In other telescopes, the smallness of the eye-glasses is very objectionable where highly magnifying powers are wanted; in compound eye-pieces particularly, (which are by far the best,) it is next to impossible to obtain them small enough. In the Stanhope telescope, the greatest powers can be obtained with glasses of not less than two inches focus; which are of a size much more manageable in every

respect. Opticians will, I believe, think this impossible, but I can assure them it is strictly true.

"In other telescopes, the eye-piece requires a very nice adjustment, as well on account of the difference in eyes, as the greater or less distance of the objects themselves; but in this instrument no such nicety was required: for with the same situation of the eye-piece, objects placed at sixty yards, or any where in his lordship's extensive park, or upon the Vine at Sevenoaks, which I think is a distance of three miles at least, were distinctly seen; nor did it require to be adjusted afresh for different observers; and what is more extraordinary, he would pull out or push in the eye-piece more than twelve inches without producing any perceptible indistinctness: his lordship thought this of great importance.

"But what will surprise opticians the most, is the result of the last *Experiment* which his lordship ever made, *on an Evening in January* 1816, *after the Sun was set.* The object was a watch-dial placed at the distance of sixty yards from the telescopes; and when it was too dark to see the dial at all with a Gregorian telescope of six inches aperture, and which had a metal of an excellent composition, with his *Telescope of* 192 *feet focus,* having the *Aperture* reduced to *three-quarters of an inch,* and charged with a *Power of three hundred* times, his lordship, as well as myself, and several others who

were present, could read the figures, and the small dots between the minute figures on the dials, the experiment being tried upon several: the dials appeared as though some artificial light had been thrown upon them, when, in truth, there was no such thing, nor any other artifice used. Now, in the common construction of telescopes, metals reflect and glass transmits light in proportion to their areas, or as the square of their aperture, which in this case was as sixty-four to one; so that the effect was produced by the peculiar construction of the instrument, and can be attributed to no other cause."

MEM. I do not insist upon my Readers believing all the above. W. K.

The late Astronomer Royal, Dr. Maskelyne, in the Preface to the first vol. of his Observations, has recorded the following comparison, "the result of many Observations* made with an excellent Achromatic telescope of 46 inches focus, with a treble object-glass, the work of Mr. Dollond, and a six feet Newtonian reflector made by Mr. Short, and a two feet Gregorian reflector made by Mr. Edwards. The Six feet reflector seemed to have the advantage of the achromatic telescope in observing the eclipses of *Jupiter's* first satellite by 13 seconds—and over the two feet reflector by 20 seconds; shewing the immersions so much later, and the emersions so much sooner†.

"The diameter of the aperture of the six feet Newtonian reflector is 9.4 inches;—that of the two feet Gregorian reflector is 4.36 inches; and that of the Achromatic telescope 3.6 inches."

The preceding comparison of the achromatic and the reflectors, does not go to support Dr. Maskelyne's assertion, that Mr. Edwards's Metals reflect as much light as Glass transmits,—the immersions of *Jupiter's*

* It should always be stated with what Aperture and Power, Observations are made—and at what distance the Objects were from the Meridian, and the day of the Month and Year.—W. K.

† This will, in some measure, depend on the distinctness of the telescope, and the sharpness with which it defines the Planet, and its Magnifying Power.

moons being seen seven seconds later than with the Gregorian reflector, whose aperture was nearly an inch larger in diameter.

I have had many Reflectors made for me by various artists, some of whom professed to make their metals after Mr. Edwards's recipe; and others, who used some compound of their own, which they thought still more brilliant and reflective; but I am quite certain that none of them shewed Objects more than half as well illuminated, as a fine Achromatic of equal aperture did—in what precise proportion the Light transmitted surpassed that reflected, I never shall pretend that I can tell the Reader exactly—but it is my own opinion and that of several scientific persons who saw the trial of my Telescopes—that the Illuminating power of an Achromatic to a Reflector is as 2 to 1, that is to say, the intrinsic brightness of the pencil of Rays from the former is double that of the latter.—See Chapter XVII. on *Illuminating Power*.

It has been proposed, that Dr. Maskelyne's experiment may, perhaps, in some degree be proved, by charging a *Gregorian* with a power of 50, and an *Achromatic* glass of equal aperture with a power of 80 times:—and that in proportion as the Instruments then exhibit objects with an equal degree of brightness,—will be the accuracy of Dr. Maskelyne's position as to their respective Illuminating power; but, as I have observed in the Chapter on *Illuminating Power*, the increase of the impediments to

Vision from the Medium which we look through increases in so high a ratio to the magnifying Power, as to prevent such a comparison.

One cause of *Gregorians* being complained of as being dark, and of the difficulty of finding an object with them, is, that they are generally made to Magnify much more than *Achromatics;* and the field of view is in inverse proportion to the Magnifying power, and also from the Tube being much shorter, it is comparatively more difficult (as every Sportsman knows) to take aim with them.

The opinions I offer on the *Illuminating powers of Telescopes* are, to the best of my knowledge and belief, as near the truth as my Eye has the faculty of judging.

In whatever I have written, my predominant motive has ever been, a desire to candidly communicate to others, the information which I fancy I have gleaned by long and expensive experience.

*The Highest magnifying power a Gregorian Telescope* will carry for Day purposes, without overbalancing its *Illuminating power, i. e.* without the vision being more obscured by the subtraction of Light, than it is assisted by the addition of Magnifying power, will be given by reducing the diameter of the large speculum into Tenths of Inches, and multiplying the sum by 2 or 3.

For *Planetary observations*, by 3 or 4, (this Rule will give you nearly the same Numbers that you will

find in Sir I. Newton's Table, at page 72,) more or less, according to the figure and reflective powers of the Specula, and the condition they are in,—especially the state of the Small Speculum. This rule only applies where the application of it does not produce a power of more than 250 times—which is the utmost that the Atmosphere of this Country ever permits us to apply to Planets:—this is fully explained in the Chapter on *Illuminating Power*.

It is almost needless to observe, that highly polished Metals of a perfect figure, will reflect more light, and shew objects more brilliantly, than tarnished Specula, originally of a bad composition, and perhaps of rather a queer figure at first.

*The Small Specula* should be closely covered with Brass caps fitting close upon them—and then packed in a Box with *the Large Speculum*—which should be kept in a dry place, and occasionally examined to see if it gets tarnished.

Specula are very easily and irreparably injured—by a Blow or a Fall, although there may be no perceptible mark of such injury except in the deterioration of the vision.

*Illuminating Power* (like other things) is most accurately estimated when it is most wanted, *i. e.* on very minute objects, and such as are badly lighted up.

The advantage of *a Large Telescope* is most ob-

vious, if the comparison is made at the close of day: as darkness comes on, the superiority of Illuminating power will become more easily visible. — See Mr. Tulley's Letter in Chapter IX. on *Cassegranians*, and XVII. on *Illuminating Power*.

*Distinctness* is frequently misnamed *Light* and brilliance. A fine Telescope is said to be remarkably light, because all the rays, by the Mirror or Object-glass being ground perfectly true, unite at one point; this uniform action produces the same strong effect as the equal bearing of every fibre of *Captain Huddart's* Cable, of which every thread pulls.

" *Crown-glass* is the most proper for the Eye-glasses of Reflecting Telescopes, as it is the most pure glass made in this country, and, notwithstanding its colour, transmits more light than even flint-glass—Objects may be seen through a much thicker piece of crown, than of Flint-glass."

" The combination of the colour of the Crown-glass, and of the light reflected from the Metals, shews objects of their natural colour, and totally free from all dingy or yellowish tinge. An Eye accustomed to use a Crown-glass eye-piece will never like any other, the Vision is so decidedly superior." — See *Appendix to the Nautical Almanack* for 1787.

The eye-tubes of Gregorians are generally formed of two glasses, and the causes which enable them to carry more magnifying power for Astronomical

than for Day purposes, is the vividness of the objects augmenting the brightness of the pencil, and their being farther removed from the Vapours which float near the Horizon.

It is not the mere diameter of the pencil, but the quality of it, that stimulates the Eye, which is as much excited, and as perfect an impression is made on the retina by a vivid pencil of light of $\frac{1}{50}$th of an inch diameter, as by one of inferior brightness of $\frac{1}{25}$th of an inch diameter.—See the Chapter on *Illuminating Power*—and the comparative brightness of the Pencil of rays from Achromatics and from Reflectors.

The hole in the large mirror of the Gregorian telescope, when the diameter of the metal does not exceed three inches at least, is so great a deduction, in proportion to its aperture, that it is not fair to compare the respective Illuminating powers of Reflectors and Refractors, with a metal of less size.

For Gregorian telescopes under this size, an Eye-tube containing only one eye-glass has been recommended, from its transmitting more light. Dr. Herschel, in one of his observations, speaks of the decided superiority of the *single Eye-Glass*, when applied to his *Newtonian*.—See the Chapter on *Galileans* and on single *Concave and Convex Eye-glasses;* and *Phil. Trans.* vol. lxxii. p. 95.

Reflectors of Newton's construction are considered

to be decidedly more brilliant than Gregory's, because more light is reflected by the *Plane** small speculum of the Newtonian, than by the *Concave* small speculum of the Gregorian;—and in the Newtonian, all the Magnifying powers being produced by changing the Eye-pieces, may easily be made equally good, and admit of the application of almost an endless variety of Eye-glasses.

Another great advantage of the Newtonian Telescope is that its Eye-pieces are unencumbered with Eye-holes—and all kinds of single and compound Eye-tubes may be applied thereto, and it affords an opportunity of proving the peculiar properties and powers of every kind of lens.

The Makers of GREGORIAN or CASSEGRANIAN Telescopes, say that those instruments *cannot be made equally perfect with the extremely* LOW *and extremely* HIGH *powers,* if the change of magnifying is produced by changing the small Specula—which are seldom equally good.

I have heard the superiority of SHORT's REFLECTORS attributed to the patient industry with which he worked his Large metals, and the very great care he bestowed in adapting the Small spe-

* This, I am told, is a most difficult thing to obtain; and most of those that pass for PLANES, are in fact, either *Concaves* or *Convexes* of thirty or forty feet focus.—See note at the end of the 5th Chapter on *Diagonal Eye-tubes.*

culum to the large one; he made a great many small specula of the same focus, and tried them one after the other, till he made a good match.

It would much improve these instruments, as well as render them more convenient for use, if Eye-pieces were employed as in the Newtonian, (see an Account of the Three or Four Feet Gregorian in the following Chapter): still the Newtonian would be superior for astronomical purposes, from the greater quantity of light it reflects, and from the pleasant position in which we observe, especially for viewing objects in high altitudes, when, instead of almost dislocating one's cervical vertebræ—we look comfortably straight forwards.

*The Newtonian stand,* as now made, with *Four* Feet, on Castors, (which ingenious piece of mechanism was contrived by *Dr. Herschel,*) still admits of improvement, by being placed on Three feet, two behind on Castors, and one before without a Castor. I have thus altered the stand of my Herschel Newtonian, and it is much more steady than when it had *Four* feet, — one of which was always Dancing.— See in Chapter VIII. on 7 *feet Newtonians,* an account of *Mr. Newman's Improved Stand.*

## CHAPTER VII.

### GREGORIAN REFLECTORS.

THE smallest Gregorian Reflector that is usually made, is

THE 1 FOOT;

this has an Aperture of $2\frac{1}{2}$ inches, and has generally one Eye-tube, and Two small Speculums magnifying about 50 and 90 times.—Two Eye-tubes would be much better than Two small speculums—because they are easier changed, and the lower power may then serve for a Finder to the high power; I advise this, especially if the Instrument is to be used for Astronomy: for I have always found it impossible to change the Small Specula without a light to shew the Eye how to direct the arm to the groove, which carries the small metal, and the light puts the visual organ out of tune for several minutes.

The Vision of this Telescope is superior to the 2 feet Achromatic, which has an aperture of $1\frac{6}{10}$ inches, but is not quite equal to the 30 Inch of 2 inches aperture.

THE 18 INCH,

with an aperture of 3 inches, is superior to the Re-

fractor of 30 inches focus, but is seldom made; the former size Reflector being preferred by those who want a Portable Telescope for Day purposes, and those who wish a more effective fixed Instrument choose

THE 2 FEET,

which has an aperture of 4 inches, and is as powerful a Telescope as our atmosphere, near the Horizon, will generally permit us to use for Terrestrial purposes, and for use at a Window, is the Instrument to be generally recommended—its shortness makes it much more convenient than an Achromatic, which, of equal power, must have an aperture of $2\frac{3}{4}$ inches, and be of 44 inches focus, as I have stated in my Table of " the Comparative Illuminating Powers of Achromatics and Gregorians."—See Chapter XVII.

I have a Gregorian Telescope of 4 inches aperture, and 15 inches long, made by Mr. Watson, which shews the *Belts* of *Jupiter* and the Division in *Saturn's Ring*, as well as I have seen these objects in my $3\frac{1}{2}$ Achromatic of $2\frac{3}{4}$ aperture.

This Gregorian shews Double Stars (see OBS. on *Castor*, in the 20th Chapter,) with a sharply defined disk, like little Planets.

The Gregorian of 4 inches aperture is often made of 19 in length, which is very handy, and of this length it may be made as perfect as of 24 inches — but as the Speculum requires more care in figuring, for such shorter instruments the Makers charge more money.

This Telescope has usually Two Huygenian Eye-tubes and Two small Speculums, magnifying 60, 90, 120, 180 times. I would recommend the addition of an Eye-tube of 40 for the Moon, and another to magnify 130 times with the lowest small Speculum — then there will be no occasion to change the small metals for terrestrial purposes, or for observing Planets — only for examining Double Stars, which require the higher magnifying powers, and for which purpose it will very well bear a power of 250, which the Eye-piece that gives the power of 130 to the largest Small Speculum will give to the Smaller one.

Each of the Eye-tubes of a Gregorian Telescope may be made to serve the purpose of producing Three magnifying powers — by merely having additional Eye-heads — and using the First Eye-glass alone—and the Second Eye-glass alone—which will give powers of similar proportions to the compound Eye-tube as those mentioned in the account of the 5 feet Achromatic, in Chapter IV. — and see also the word *Huygenian* Eye-piece in the INDEX.

This Telescope must be furnished with a Finder, which should be a 1 foot Achromatic, with an erect Eye-tube magnifying 10 times — as it will be useful for Terrestrial as well as Celestial purposes — as the vision is erect in the Telescope, it ought to be erect in the Finder also.

This is the largest Gregorian that can be used pleasantly on a simple Pillar and claw stand, on which it must be nicely balanced when the Cover of

the Object-end is taken off—but this Telescope is much steadier when mounted with Rack-work in the centre of its gravity; this increases the expense of the Instrument: however, if it is to be used for Celestial purposes, it will be money wisely laid out, for the weight of the Speculum otherwise sometimes overbalances the Object-end, and renders the Instrument very unmanageable.

THE 3 FEET,

with an aperture of 5½ inches, is the smallest-sized Gregorian I would recommend for Astronomical purposes—especially for viewing the Belts and the Division in Saturn's Ring, which latter is not well seen with a less Speculum,—but I advise the Philosopher who can prudently spare £42, to stretch his purse-strings a little wider, and give £105 for

THE 3 OR 4 FEET LARGE GREGORIAN,

with an aperture of 7 inches—these, are now mounted on excellent Rack-work, and have a portable, folding, but very steady tripod Stand, which renders them extremely convenient to use both for Celestial and for Day purposes; and they shew the features of Jupiter and Saturn in a very satisfactory manner; and when perfectly good, they are very little inferior, for observing Planets, to the 7 feet Newtonians: I think that they are not quite so light as Newtonians of the same aperture.

This Instrument should have five Eye-tubes and at least two small metals.

| | Lowest Small Metal. | Deepest Small Metal. |
|---|---|---|
| Longest Eye-tube.......... | 45 | 90 |
| 2d, ...................... | 80 | 160 |
| 3d, ...................... | 130 | 260 |
| 4th, ..................... | 180 | 360 |
| 5th, ..................... | 250 | 500 |

For the application of these Powers, see Chapter VIII. on the 7 *feet Newtonian.*

Gregorian Telescopes are more easily managed by Persons not used to Telescopes than *Newtonians,* except for observing those Celestial objects which are very near to the Zenith.

*A Nine Inch Speculum* may be worked of 27 inches focus (I have a Gregorian of that size), and supported on two arms in the centre of Gravity, and fixed on a Block—so as to be as portable as a 7 *inch* Speculum.—This might be done for about £150.

For *the Comparative Powers of Reflecting and Achromatic Telescopes, see the Table in the last pages of Chapter XVII. on Illuminating Power.*

# CHAPTER VIII.

## OF THE 7 FEET NEWTONIAN REFLECTOR.

THE attention of Astronomers has been so extremely excited by the extraordinary accounts which *Sir W. Herschel* has given, in various Numbers of the *Phil. Trans.*, of the astonishing performance of his 7 feet Newtonian, of $6\frac{3}{10}$ inches aperture, that this Essay on Telescopes would be incomplete, unless it contained some Observations made with a Newtonian of that length and aperture :—at the sale of Mr. Hodgson's Instruments, one of *Sir W. Herschel's* own 7 feet Telescopes came into the market, which I purchased of Mr. Jones, Optician, in Holborn, who bought it at Mr. Hodgson's sale, at Mr. Sotheby's Auction Rooms, Waterloo Street, Strand.

Sir W. H. very justly remarks, that "The Newtonian, as usually constructed, is admirably adapted for observation, for the Observer always stands erect, and looks in an horizontal direction, though the Telescope should be in a vertical position, and elevated to the very Zenith."

The Position in which it was placed by this ingenious Astronomer is perhaps still more natural and convenient.

"My Eye-glass is mounted on that side of an

octagon tube, which, in the horizontal position of the Instrument, makes an angle of 45° with the vertical—having found by experience that this position, resembling the situation of a reading desk, is preferable to the perpendicular one commonly used in the Newtonian construction, which has the capital advantage of rendering observations equally commodious in all altitudes; and you may therefore place the Instrument in the meridian, and view the Stars in their most favourable position."—See *Phil. Trans.* for 1786, vol. lxxv. pp. 457 and 8.

I have no hesitation in declaring, that in the unpleasant (and if long continued, painful) Position required in observing Celestial objects in high altitudes, with any other Telescope—that no Half Dozen Observers, even if as Experienced, and as Expert, and as Industrious as the IMMORTAL HERSCHEL himself, could have performed what that indefatigable Observer achieved Single-handed with his 7 Feet Newtonian.

The 7 Feet Newtonian mentioned in the preceding page was made by Sir W. H. expressly for Mr. Hodgson, who had at that time several very fine Telescopes (see the end of the Chapter on *Cassegranians*), and therefore it may be presumed that every pains was taken by Sir W. H. to make this 7 feet worthy of being compared with Mr. H.'s other Instruments.

This Newtonian is fitted up with One Compound

Eye-tube composed of 2 double Convexes—which magnifies 75 times, the field of which just holds the full Moon—and 8 other Eye-pieces, each of which consist of a single double Convex lens, not burnished into a cell as Eye-glasses usually are, but simply laid in a cell and the Eye-head screwed over them, like as the Object-Glasses of Microscopes are fixed—and by Ramsden's Dynameter the powers of the 5 first lenses are 94, 157, 197, 242, 350.

The Three higher Lenses are only useful as evidences that Magnifying power beyond a certain boundary, does more harm than good.

Mr. Hodgson several times told me that he requested Sir Wm. H. to let him have exactly the same Instrument in every respect as the 7 feet, which was Sir Wm. H.'s favourite working tool—and fitted on the same sort of Stand, and with exactly the same apparatus and Magnifying powers, &c.; but Mr. Hodgson complained to me, that the deepest Lens which Sir W. H. had given him, was no shorter than the 40th of an inch focus, and consequently did not magnify much more than THREE THOUSAND Times: and that Sir W. H. had forgotten to send him the power of 6450!

Once for all, I will remark, that people are under a strange delusion about this power of 6450. Sir W. H. only mentions having used it *twice* in the whole course of his writings, which is at *α Lyræ* and at *γ Leonis*.—See Chapter XX. on *Double Stars*.

Both these Stars I have observed with my 7 feet Herschel Newtonian with lenses of the $\frac{1}{10}$th, $\frac{1}{20}$th, and $\frac{1}{40}$th, of an inch focus, and I must confess that all the Eyes that have looked through that Instrument have agreed with my Eye, that a lens of $\frac{1}{10}$th of an inch focus, which gives a power of 840 times, is twice as much as is needful for real use—that is to say, they are seen more distinctly and are more sharply defined with 420.

This Newtonian of Sir Wm. Herschel's has been tried by several practical Opticians, and they pronounce it to be a very good Instrument—and after repeated comparisons and trials of its various powers on various objects, I think that it is.

If I was to order a Telescope for Astronomical purposes, for my own use, I would have a Newtonian, of neither more nor less than 7 feet focus, and 7 inches, or, if I could get an Optician to work it, of 9 inches aperture.

Among other advantages which the Newtonian possesses, is the greater facility of applying all kinds of powers and Eye-pieces to it than we have with other Reflectors.—A Single Convex—or Concave Lens may be applied to a Newtonian without any apparatus of Eye-hole, &c.

The various advantages of Newtonian Telescopes, for Celestial purposes, are stated in various pages in this work—where I wrote them down as the facts struck my mind at the moment that I first observed

them — in Chapter VI., on *Reflecting Telescopes* — XVII., on *Illuminating Power* —V., on *Concave and Convex Lenses*—IX., on *Cassegranian Telescopes*—and XIX., on *Saturn* — and see *Sir I. Newton's* Account thereof, and *Mr. Hadley's*.—I once thought of collecting the several Observations under this head, — but that would have cost me much time; however, I would not have minded that, if I had been quite sure that such a sacrifice of my own time would have ultimately saved much to those who need such information—but persons who really wish to thoroughly comprehend the real and relative powers of Telescopes, must carefully read the whole of this little Book over and over again, if they wish to be entirely Master of the intricate subjects which I have endeavoured to explain,— not but that I have taken the utmost pains to write down my ideas in as plain terms as possible, but that there is such a multitude of strange prejudices, and such numberless Vulgar Errors afloat on Optical subjects, — that only a continued concatenation of reasoning will thoroughly convince and set the mind at rest about them.

*The Tubes of Sir Wm. Herschel's 7 feet Newtonian Telescopes* were made of Mahogany: — however well-seasoned the Wood may be, still it is so easily, and so much, and so continually affected by any change of the Temperature of the Air, that to *perform perfectly, the Instrument must be adjusted almost every time it is used*—and therefore Persons using such Telescopes must learn how to adjust them accurately, or they

will be of very little use :—to prove the variation of adjustment—if you adjust the Finder to the Telescope in the Morning so exactly that when an object appears in the centre of the Telescope it is exactly in the centre of the Finder ; you will rarely find when you examine it at night, that they exactly correspond: I suspect that this deviation sometimes arises from the change in the position of the Specula from the change in the Tube. Sir W. H. was so conscious of this that his large metals are adjusted by *Two* Screws :—there should be *Three.*

By Sir W. H.'s mode of fixing the Large Speculum, it cannot be taken out of the Tube without entirely destroying the adjustment of it—therefore Sir W. H. fitted a Brass Cover to it, which is put over it while it is in the Tube, to prevent the damp from tarnishing it; and as the Box which holds the Large Metal is not secured by a *Third* Screw, every time you take off the Brass cap which covers the Large Speculum you unavoidably alter the adjustment of it: the Metal is not only loose in the Box—but the Box being fastened by only *Two* Screws—both the Metal and the Box are continually varying in their position.

I was surprised to find, that after I had adjusted my 7 feet Herschel Telescope in the Daytime, and that when laying horizontally it was extremely distinct, and the metals appeared quite in their proper place, and the centre of the field of the Telescope and that of the Finder perfectly corresponded,—that

the same evening, on looking at a Celestial Object, when elevated about 35 degrees, the centre of the Finder and that of the Telescope varied very much, and the pencil of rays, instead of appearing perfectly round, as it did in the daytime — was of the same shape that the Moon is about 2 or 3 days before it is full, and the Small Metal was removed considerably from the centre of the Large one: accordingly, the first fine Moonlight Night I adjusted the Large Metal (by turning the screws at the back thereof) when the Telescope was elevated to about 35 degrees — it then performed on several Celestial Objects quite beautifully.

"Mr. Hadley supported the great Speculum of his Telescope at the back, not by Springs, but by Three Screws, directly answering to the Three bearings on the Fore Part." — See the Appendix to the *Nautical Almanack* for 1787, page 60.

*Telescopes in Brass or Iron Tubes* are not so liable to these variations, and I recommend a Brass or Iron tube where fine vision is desired, also because the Metals do not require to be continually covered up, which they must be in Mahogany Tubes — or they will very speedily be destroyed by Tarnish.

You will find it convenient on first looking through a Newtonian Telescope to use the lowest power — that is, the Moon Eye-piece, which is generally an Huygenian Eye-tube magnifying about 50 times — which having a large field, you may easily find an

object with it—and then set your Finder right, or rather, turn the adjusting Screws at the back of the large Speculum till the Telescope is right with the Finder, which thus serves as a criterion of the proper adjustment of the Telescope:—but if the deviation in its adjustment be considerable, desire the maker of the Telescope to examine it, and see if there be not some defect in the construction of it which is remediable.

*To examine the Adjustment of a Newtonian Telescope, and how to rectify it.*

Take out the Eye-piece—leave in the lengthening piece—and screw into that your lowest Huygenian Eye-tube, out of which you have taken both Glasses, and left in the Eye-hole; look through this, and if the Metals are in adjustment—you will see the image of the Small Speculum exactly in the centre of the Large one—and you will see just the edge of the tube at equal distances around the Large Metal: when this is not so, while you are looking in at the Eye-hole, let another Person very gradually turn the adjusting screws at the back of the Large Metal, till it comes right, which you will find you will soon learn to make it, with very little time or trouble.

Dr. Herschel informs us that he found by experiment that "it was impossible to apply Springs to a Large Speculum of more than 5 inches diameter, because if they were not very stiff they would yield

to the weight of the Speculum in high altitudes, and so alter the adjustment; and if they were made very stiff, that they spoilt the figure of the Speculum."— See p. 60 of the Appendix to the *Nautical Almanack* for 1787.

Dr. H. put his larger Specula into a Brass Box, leaving a certain quantity of space for their occasional expansion. Mr. TULLEY informed me, that he thinks that the Dr. sometimes allowed too much room for their play in this Box, and that that is the cause, why his metal, when in adjustment for an horizontal position, sometimes, is not in adjustment when elevated to different heights.

Mr. T. had one of Dr. H.'s 7 feet Newtonians brought to him to make it fit close in its Box, and by so doing he thought the vision of the Instrument was improved, and uniform in various temperatures and at various degrees of elevation—however, from some cause, the Telescope was sent again to Dr. H., and when returned from him to the proprietor of it the Dr. had again altered the Box containing the large metal, and given it its former quantity of play.

Mr. TULLEY informed me, that by his method of boxing and adjusting his large metals, that when once in adjustment, they remain so; and may also be taken out of the Tube and returned thereto, without any danger of deranging their position.

Much has been said *pro* and *con* the respective

advantages of supporting Specula with Springs and with Screws.

Mr. WATSON and Messrs. TULLEY, in the Gregorian Telescopes of 7 inches aperture, always apply brass springs, as decidedly preferable to screws; if such Springs are best in Gregorians of that aperture, they must be best in Newtonians;—for the Newtonian metals are very little heavier than the Gregorians are.

Springs may by their elasticity admit of that self-adjustment of the Speculum in various Temperatures, which is only accurately obtainable with Screws, by altering them as often as the Thermometer alters, which may explain the cause why Mr. Mosely, in his Letter to Mr. TULLEY, (see page 145) complains that his 7 feet Newtonian will not act in *cold* weather—*i. e.* if his metal is supported by Three Screws which were adjusted in *warm* weather.

An experienced Amateur of Telescopes observed to me, that perhaps the Speculum of a Reflector was never of perfect figure except when the Air was of exactly the same Temperature as it was at the time it was worked—this idea very satisfactorily accounts for Reflectors performing best in warm weather—because large Metals are never worked but in warm weather, *i. e.* above 60 of Fahrenheit.

*Springs* have been applied to the Strings of Piano

Fortes in order to preserve them in tune, and I have heard with very good effect.

The large Speculum of a Newtonian is generally a little heavier than that of a Gregorian — because being cast in the same mould, and more of the face of the metal being worked off in forming the deep curve required in Gregorian Metals, than it is in the shallow one of Newtonians — and the hole in Gregorians is larger than it is in the Newtonian ;—however, all this is written here merely to shew the Reader that the Writer has considered these subjects with minute attention; the difference in weight is of no consequence at all.

The Tremors which old authors talk off — must have been occasioned by some other cause than that alleged, the Springs which supported the large Metal.

It has been supposed, that the superior Illuminating power of Sir Wm. Herschel's telescopes of the Newtonian form, beyond Gregorian Reflectors, arises partly, from there being no hole in the middle of the large metal: — but that portion of the metal which is perforated in the Gregorian, is obscured in the Newtonian by the Plane Small Metal, which is almost as great an obstacle as the Concave Small Speculum of a Gregorian.

That excellent Workman, Mr. WATSON, informed me, that he preferred to make a Newtonian large metal with a small hole, because it was much more handy to work, and also that the metals can thereby

be much more easily and accurately adjusted to each other, which gives those that are thus perforated a chance of being much better Telescopes; and that part of the metal where the hole is, being hidden by the plane Speculum, they are quite as light as those which are not perforated.

Mr. WATSON's plan of fixing the large Speculum of a Newtonian telescope is to put it into a Brass Box, in the front of which are three Stops, and behind the metal are three brass springs directly opposite to the three stops, to keep the metal up to them — if these Springs are not placed *directly* opposite to the Bearings in front, they will spoil the figure of the metal. The rim of this Box bears against Three stops in the Tube, which are adjustable, and when once adjusted remain so — this Box with the Metal in it is placed in the Tube against these three stops, and is kept there by a tail-piece which has three springs — which keep the Box close up to the three Stops in the Tube,—to ascertain that they are in the right place, take out the metal, screw in the front plate, and look in at the Object-end.

I mention this method of supporting the large metal because I had a 7 feet Newtonian so constructed by Mr. WATSON—which defined a fixed star very neatly, and performed better than any of those I have seen which had the adjustment, &c. by Screws. Moreover, by this plan, the large metal is as easily taken in and out as an Eye-tube—therefore.

instead of being either obliged to leave your large Speculum in a damp Tube in a damp Observatory— or have the trouble of adjusting it every time you take it out of the Tube—you may take it out with the utmost ease, and put it in its dry tin box in a dry place; and by so doing, you have an opportunity of observing if it gets tarnished, and of wiping it off, which can be done easily at first by breathing upon it, and as the breath is going off rubbing it with a bit of *clean* lamb's-skin—but with difficulty after it has been on a little time.

It appears by the following statement of Mr. EDWARDS, that a very trifling degree of pressure will prevent the proper action of the great Metal.

" I can at any time totally spoil the figure of a metal by wedging it only with the thickness of a bit of common writing-paper. *Dr. Smyth* says, that One *thousandth* of an Inch will spoil its figure. I am sure also, that that quantity, if not less, will injure it. If the metal was made to rest at Two Points, each of which is 45° from the bottom and 90° from each other, I think the Figure would not be injured at all. I do not see that the Thickness of the Metal is of any Service to prevent this small Degree of Bending, for I never yet saw a large Metal whose Figure I could not spoil with an exceeding small Pressure at its Back. Nor do I approve of Three Screws at the Back to bear against the Metal, as I altered my own small Telescope to that Plan, and I never could

make the Screws bear equally alike, but they would bear harder against one Place than another, and so spoil the Figure. I think they had best be fastened by Three small Screws passing through the Tube perpendicular to the Axis, and of such a Thickness as for their Sides to touch the Back of the Mirror barely without any Shake. By removing the Brass back (viz. the Brass into which the Eye-piece is screwed), you may see the Screws bear Sideways against the Mirror in Three Places, and may file away the Sides of the Screws so as to make them just touch the Mirror, but not much more."— Appendix to the *Nautical Almanack for* 1787, p. 54.

A PAPER (from p. 173 of the *Phil. Trans. for* 1782) TO OBVIATE SOME DOUBTS CONCERNING THE GREAT MAGNIFYING POWERS USED BY MR. HERSCHEL, F.R.S. ADDRESSED TO SIR JOSEPH BANKS.

"SIR, I have the honour of laying before you the result of a set of measures I have taken in order to ascertain once more the powers of my *Newtonian 7 feet Reflector.* The method I have formerly used, and which I still prefer to that which I have now been obliged to practise, requires very fine weather and a strong sunshiny day; but my impatience to answer the requests of Sir Joseph Banks would not

permit me to wait for so precarious an opportunity at this season of the year. The difference in all the powers, as far as 2010, will be found to be in favour of those I have mentioned; and, I believe, a much greater concurrence could not be well expected, where different methods of ascertaining them are used. The variation in the two highest powers is more considerable than I was aware of; but still may be shewn to be a necessary consequence of the difference in the methods. However, if, on comparing together the methods, it should be thought that the power 5786 is nearer the truth than 6450, I shall readily join to correct that number.

"*The manner in which I have now determined the Powers is as follows:* I took one of the eye lenses which magnifies least, and measured its solar focus by the sun's rays as exactly as I could five times, which proved to be 1.01, 1.04, 1.09, 1.01, 1.05, in half-inch measure, a mean of which is 1.04. The sidereal focus of my 7 feet speculum is 170.4 in the same measure. Thence, dividing 170.4 by 1.04, we find that the telescope will magnify 163.8 times when that lens is used. This power being found, I applied the same lens as a single microscope to view with it a certain object, which was a drawn brass wire fastened so as not to turn on its axis or change its position; for these wires are seldom perfectly round, or of an even size, and it is therefore neces-

sary to use this caution to prevent errors : then, with a fine pair of compasses, I took four independent measures of the image of the brass wire, which was thrown on a sheet of paper exactly 8½ inches from the lens, the eye being always as close to the lens as possible. I viewed the same wire, exactly in the same manner, with every one of the lenses, and measured the pictures on the paper. When I came to the higher powers, the wire was exchanged for another, 4.37 times thinner than the former, as determined by comparing the proportion of their images 54 to 235¾, taken by the same lens.

"When the images of these wires are obtained, the power of the telescope, with every one of the lenses, becomes known by one plain analogy: viz. as the image of the wire by the first lens (77¾) is to the power it gives to the telescope (163.8), so is the image of the wire by the second lens (119), to the power it will give to the same telescope (250.7). The particulars of all the measures are as follow :

| Powers as they have been called in my papers. | Images of a wire thrown on a paper in hundredths of half-inches. | A mean of the four measures. | Powers as they come out by this method. |
|---|---|---|---|
| 146 | 77.. 78.. 78.. 78 | 77¾ | 163.86 $= \frac{170.4}{1.04}$ |
| 227 | 119..119..119..119 | 119 | 250.7 |
| 278 | 143..143..144..143 | 143¼ | 301.8 |
| 460 | 236..236..235..236 | 235¾ | 496.7 |
| | Smaller wire. | | |
| | 53.. 54.. 55.. 54 | 54 | |
| 754 | 83.. 85.. 84.. 85 | 84¼ | 775.1 |

| Powers as they have been called in my papers. | Images of a wire thrown on a paper in hundredths of half-inches. | A mean of the four measures. | Powers as they come out by this method. |
|---|---|---|---|
| 932 | .. 107..107..107..108.... | 107¼ | ....986.7 |
| 1159 | .. 128..128..129..128.... | 128¼ | ....1179.9 |
| 1536 | .. An excellent lens, lost about 8 months before. | | |
| 2010 | .. 236..236..238..236.... | 236½ | ....2175.8 |
| 3168 | .. 281..283..281..280.... | 281¼ | ....2585.5 |
| 6450 | .. 635..625..630..626.... | 629 | ....5786.8* |

"I beg leave, Sir, now to give a short description of the method I have formerly used to determine these powers. In the year 1776, I erected a mark of white paper, exactly half an inch in diameter, which I viewed with my telescope at the greatest convenient distance with one of the least magnifiers. An assistant was placed at right angles in a field, at

* Opticians have a scale with which they can easily and accurately ascertain the focal length of a lens to the $\frac{1}{100}$th of an inch. The focal length being known, you have only to multiply the focal length of the Object-Metal or Object-Glass, by the focal length of the Eye-Glass, and you have the magnifying power, without a possibility of error: thus, to make a Newtonian of 84 inches focus magnify upwards of 6,400 times, requires an Eye-Glass of less than the 75th of an inch focus. For example —

84 focus of Object-Metal.
75 focus of Eye-Glass.

420
588

6300 magnifying power.

The above Note is by W. K.

the same distance from my eye as the object from the great speculum of the telescope. On a pole erected there I viewed the magnified image of the half inch, and the assistant marked it by my direction; this being measured, gave the power of the instrument at once. The power thus obtained was corrected by theory, to reduce it to what it would be on infinitely distant objects. The powers of the rest of the lenses I deduced from this, by a camera eye-piece, which I made for that purpose. A B C D (fig. 17, pl. 3) represents a perpendicular section of it. The end A screws into the telescope. On the end B may be screwed any of the common single lens eye-pieces. l m n is a small oval plane speculum, adjusted to angle of 45° by three screws, two of which appear at o p. When the observer looks in at B, he may see the object projected on a sheet of paper on a table placed under the camera piece, and measure its picture a b, as in fig. 18. The power of one lens, therefore, being known, that of the rest was also found by comparing the measures of the projected images.

"It may not be amiss to mention some of the advantages and inconveniences attending each of these methods. When we take the focus of an eye-lens, which the first method requires, we are liable to a pretty considerable uncertainty, and in very small lenses it is not to be done at all. Also, in calculating the power by that focus, no account is made of

the aberration which takes place in all specula and lenses; and increases the image, so that we rather find out how much the telescope should magnify, than how much it really does magnify; but in determining the power by an experiment we avoid these difficulties. On the other hand, when the power is very great, the latter method becomes inconvenient, both on account of want of light in the object, and a very considerable aberration which takes place, and makes the picture too indistinct to be very accurate in the measure, and of course larger than it ought to be; and this will account for the excess in the measures of my two largest powers. However, when I employed 6450 on the diameter of *α Lyræ*, I incline to think the method I had used when I determined that power, ought to be preferred, because my lamp-micrometer gives the measure of an object as it appears in the telescope, and therefore this aberration is included, and should be taken into consideration.

"To prevent any mistakes, I wish to mention again, that I have all along proceeded experimentally in the use of my powers, and that I do not mean to say I have used 6450, or 5786, on the planets, or even on double stars; every power I have mentioned is to be understood as having been used just as it is related, but further inferences ought not as yet to be drawn. For instance, my observations on *ε Bootis* mention that I have viewed that star with 2010, or as in the

above table with 2175, extremely distinct; but on several other celestial objects I have found that power of no service."

I shall not here offer one single Comment on the Great Powers which Sir W. Herschel mentions having used with his own 7 feet Newtonian of $6\frac{3}{10}$ths Aperture—but refer the Reader to the preceding paper thereon : I shall merely state what Eye-pieces my own Eye chooses for such an Instrument, for the various Objects that it is usually applied to.

1st. a Power of 15 or 20 for *Comets,* and *Nebula, Milky Way,* &c.

2d. ——— 45 and 60 for the *Moon.* Those who have not seen the Moon with a Newtonian, or a very long Achromatic with a large aperture, may be said not to have seen it at all—the vision is so much more beautiful for it in this than it is in other Telescopes—to view the full Moon, have an Aperture of 4 inches cut in the Cover of the Object end of the Telescope, which is too light on this object for the Eye to bear with the whole aperture, or have a light Green Glass to fix on before theEye-tube :—this contracted Aperture or Green Glass will also be useful for viewing the *Sun,* and *Venus,* and for comparing this Instrument with Achromatics and other Telescopes—and shewing the effect of *Illuminating* Power.

3d. a Power of 80 for *Jupiter* and his Moons, or for shewing a Planet to another person, as it has a very large field.—See Chapter XI.

4th. ——— of 150 for *Jupiter* and *Saturn.*

5th. ——— 200 Ditto, very pleasant and satisfactory.

6th. ——— 250 Ditto, utmost useful power for *Planets.*

7th. ——— 400 *Double Stars.*

By increasing Magnifying Power beyond 400,—I find that I only increase the difficulty of using my Telescope—with a higher power, almost every Object which I have examined appears less distinct instead of being better defined.—See Chapter XIV. on *Magnifying Powers and Eye-pieces.*

I would recommend the foregoing Eye-tubes to be of the Huygenian construction. The very same Eye-tubes which make my 3½ feet Achromatic magnify 80, 130, and 180 — give my 7 feet Newtonian about 150, 250, 330.

Sir Wm. H. recommends, for observing *Saturn,* a Single Convex lens magnifying 287 times — I have tried a single Convex of 280 at Saturn, but with that power the features of the planet were not seen more plainly, and the diminution of the field of view, and the increased rapidity of the object passing it, was an inconvenience: 250 is quite as high a power as this, and I may say, as any Telescope, however large, will carry with any advantage, either for

*Jupiter* or *Saturn*—for which I prefer 218.—See Chapter XIX.

Dr. Maskelyne says, that *Short's Dumpy*, which was a very fine Cassegranian of 6 inches aperture, would not bear a higher power than 231.—See the preceding Chapter VII.

I have also a *Polycratic Wheel* of six single double convexes, magnifying 100, 200, 350, 500, 800, 1600—the Two last are useful for no other purpose than merely to prove that such monstrous Magnifiers are useless ;—they are about as properly adapted for actual and accurate observation, as the Monument is for a Toothpick.

The three first of these Single Lenses serve to compare with the Eye-tubes composed of Two glasses.—See more on Magnifiers in the Chapters XIV., on *Eye-pieces*—XVII., on *Illuminating Powers*, &c.—and V., on *Concave and Convex Single Lenses.*

A Box 18 inches long, 14 inches wide, and 10 inches in height, is an indispensable assistant to this Telescope, as even if the hinder winch is let down first,—which it ought to be ; when the object of observation is elevated above 65 degrees, the Eye-tube becomes too elevated for easy access—or I prefer a set of 4 Steps rising about 4 inches above each other, with a Pole attached to them to lean against—this is a very convenient assistant to keep the observer steady.

THE FINDER is a more necessary appendage to a

Newtonian than to any other Telescope, and should be an Eighteen inch Achromatic telescope with a double eye-glass, magnifying about seven times — it should be adjusted by Two Finger Screws bearing against a Spring; and in order to get the Eye to it easily, it must stand out from the Tube of the Telescope about Three inches.

The Finders of Newtonian Telescopes are sometimes made with a Diagonal Eye-tube in order to save trouble in using it — however, the Old Proverb that "the longest way about is the shortest way home," applies very aptly in this case; and such a Finder as I have mentioned above is much more convenient than a Diagonal one, for we must look along the tube to find the Object for the Finder. — See the article *Finder* in the Index.

LASTLY — To give a large Reflecting Telescope a fair chance of doing its best—it must be used on the Ground, and *in the Open Air;* in which situation, with the Metals both uncovered, it should be placed (especially if it have a Wooden Tube) *at least a quarter of an hour before you attempt to look through it.* — See *Obs.* in Chapter VI., on *Reflectors,* and Mr. TULLEY'S *Letter.*

The STEADIEST, the SIMPLEST, the CHEAPEST, and the most convenient STAND, that I have seen for a Newtonian, was made by Mr. NEWMAN, *Carpenter, No. 2 Mary Place, Mary Street, Brook Street, New Road,* near Tottenham Court Road.

This extremely ingenious person made every part of his Newtonian Telescope with his own hands.

MR. TULLEY'S *Letter.*

*Dear Sir,*

THE best reply I can make to your Queries respecting the performance of a 5 feet Achromatic of $3\frac{8}{10}$ths aperture, and a 7 feet Newtonian of $6\frac{8}{10}$ths aperture, is to send you the following Extracts from Letters from Mr. MOSELY, of Winterdyre House, near Bewdly, who has a very fine 5 feet *Achromatic of my making, which was formerly in the possession of Mr. BARTLEMAN, the Singer, and has also one of the best 7 feet Newtonians that I ever finished, as the following Observations, in Mr. Mosely's own words, will certify. I took every pains to make these Telescopes as perfect as possible — and nobody knows how to use them better than the Gentleman who writes me the following Observations, on the correctness of which you may confidently depend.

I am, Dear Sir,

Your humble Servant,

CHA. TULLEY.

Territ's Court, Islington,
January 13, 1825.

## EXTRACTS FROM LETTERS FROM MR. MOSELY TO MR. TULLEY.

October 1821.

"THERE is something about my 7 feet Newtonian which I cannot understand. I paid great attention to it during the few remarkably clear, warm, and calm nights, which we had in August. At that time, ε *Bootis* and η *Coronæ*, were in a good point of view. With the Eye-piece marked 420 (a single lens in the wheel) I could see η *Coronæ* most distinctly; yet ε *Bootis* was surrounded by circles of false light, so as to be scarcely defined at all; and when a bright Star was examined, it appeared as a blaze of light, without the least appearance of any defined disk—how can this be accounted for? The same night your 5 feet Achromatic defined ε *Bootis* without the smallest particle of false light or Rings playing about; and even α *Lyræ* was defined most beautifully, so that the small Star was visible. I could not, however, see η *Coronæ* with this Glass; the highest power that I could use distinctly only elongated it.

"From hence it appears, that although the 7 feet Reflector does not equal the 5 feet Achromatic in shewing a bright Star well defined—it will define less bright objects which are smaller in a better manner."

Nov. 11, 1821.

"I HAVE never been able to get the 7 feet Newtonian to act, except in *clear* and *mild* Evenings—COLD *air*, however clear, does not allow it to perform well, not even if put out for an hour or more, to acquire the same temperature as the air.

April 29, 1822.

"I HAD last night a most beautiful view of all the most difficult double Stars of Herschel's Catalogue—the 7 feet Newtonian performed most admirably, but it was the only night which it would act since it came back. I saw in the most distinct manner *η Coronæ,* and also *h Draconis,* very beautifully: the latter is said never to have been seen out of Herschel's Garden, but that is not a fact I presume—I had never before seen it. I used the 3d power in the wheel, marked by your son 560."

July 4, 1822.

"*α Lyræ*—Your 5 feet Achromatic and 7 feet Newtonian, shew the small star near *α Lyræ,* very clear: I generally look for it by putting the large Star out of the field a little; and when once the small star is found, I can see it at the same time with the large Star."

"For my Newtonian, it is necessary to have very fine, mild, and calm weather—*cold air,*

however clear, does not allow the Reflector to perform well. It is a great misfortune that Specula are so uncertain, and that they require such nice weather to make them act perfectly—Achromatics are much preferable in this respect, as far as they go."

See Dr. HERSCHEL's Paper "*on the Causes which prevent Mirrors from shewing Objects distinctly,*" in Chapter XVIII. of this work.

## CHAPTFR IX.

### CASSEGRAIN'S REFLECTING TELESCOPE.

THIS Instrument has been seldom made, except by a few Artists and Amateurs, who have chosen it merely for the convenience of its shortness — the distance between the Large and the Small Speculum, being less in *Cassegrain's* than it is in *Gregory's* Telescope, by twice the solar focus of its Small Speculum, by so much may the tube of the Telescope be shorter— *i. e.* in a Cassegranian Telescope of 6 Inches focus the tube need not be more than 7½ Inches in length.

However charming this curtailment of tube may be to DUMPY * Fanciers, any convenience arising therefrom, has been considered to be more than counterbalanced, by the inconvenience of its shewing objects Inverted, and consequently being calculated only for Celestial purposes, — unless an Eye-tube, composed of 4 Glasses, like the Terrestrial Eye-tube of an Achromatic telescope, be applied to it, and this makes it longer than the Gregorian Telescope.

The Majority of the purchasers of a Telescope

* This appellation was first given by Mr. SHORT, the celebrated Maker of Reflectors, to a Telescope which he made for the Honourable *Topham Beauclerc*, of 6 Inches Aperture, which I saw in *Colonel Aubert's* Observatory, at Highbury; it was only 24, instead of the length he usually made them, *i. e.* 36 Inches focus.

want it to be "A Servant of All Work," and prefer an Instrument, which is also a Day Plaything—

> A Spying Glass "to see a Ship at Sea,
> "Geese on the Green, or Crows upon a Tree."

This Rhyme, is the only reason which the Author can give, why so few

NEWTONIAN TELESCOPES

have been made; for the comfort of position in observing Celestial objects, besides their other advantages, would certainly, otherwise, have recommended them to others, as well as to the really scientific and practical and persevering HERSCHEL.—See further *Obs.* on *Newtonians*, in Chapter VI. on *Reflecting Telescopes*—and in XX. on *Double Stars*.—See Sir ISAAC NEWTON's account * of his Telescope, in

* "In this paper we have the description of *the First Reflecting Telescope* that was ever made, as far as we know. The idea had, indeed, been mentioned a few years before, viz. by Mersenne, in a letter to Descartes, who did not approve of it; and again, by James Gregory, in his Optica Promota, who endeavoured in vain to carry the idea into execution. Those attempts, however, were suggested by a motive far inferior to that of Newton, being intended, besides shortening the Telescope, to avoid the errors arising from the figures of the Lenses; whereas that of our author was to obviate the error and inconvenience of the coloured images, and of the unequal refraction of the rays of light; a splendid discovery, which had but just before been made by himself." This Note is from the foot of page 691 of vol. i. of the *Phil. Trans.* abridged, 4to. 1809.

the *Phil. Trans. for* 1672, at page 4004 of vol. vii.—and Mr. HADLEY's paper in Chapter XIX.

To enable the Reader to measure the relative Reflecting powers of *Plane*—*Concave*—and *Convex* small Specula, I shall lay before him their respective pretensions, commencing with Sir ISAAC NEWTON's Papers thereon, and thence proceeding with those Practical Observations, which I have been favoured with by several scientific opticians, especially by those experienced Makers of Reflecting Telescopes, Mr. WATSON, Messrs. TULLEY, and Mr. CUTHBERT, who have given me their Notes thereon, and the account of the Facts which they have actually ascertained in the course of their numerous experiments with Telescopes of various constructions. The Opinions of these eminent Practical Opticians, which I have printed here in their own words, are perfectly unanimous, and in perfect unison with those published by Sir I. NEWTON,—and their Evidence and their Arguments are so true, and so convincing, and so plainly stated, that I think they will be perfectly satisfactory, and will finally settle certain important points, which without such Illustration, seem to me, likely to remain as they are at present—

"Puzzled with Mazes, and perplexed with Errors."

*Mr. Cassegrain's* Telescope has had its advocates; and among them Persons who have displayed such discrimination on some subjects, that it may excite

some surprise how they should have been so greatly deceived in the view which they have taken of this: but to Whom is it given to be—*Always Right?*

"Nemo Mortalium omnibus horis sapit."

The highest Praise that Humanity has pretension to, is to be—*Seldom Wrong*.

In the *Phil. Trans.* vol. lxix. p. 419, and in vols. ciii. and civ. the Reader will find Papers in praise of Cassegrain's Telescope, on which I only remark, that they are not in unison with the following by Sir ISAAC NEWTON—and that they are contrary to the experience of all the Opticians and Astronomers with whom I have conversed on the subject;—I have given an abstract of them after Sir ISAAC NEWTON's Paper.

"*Disputes on Philosophical subjects* may be managed with the utmost Candour, Respect, and Friendship, by Disputants whose only Aim is the search of Truth." See p. 4 of Dr. H[illegible]'s Preface to vol. xxix. of the *Phil. Trans.*

I have not invented any Comments to amuse you with on either of the Essays alluded to above; it never was my Pleasure to criticise the endeavours of Ingenious Persons, who have recorded the results of their Experiments, in the belief that they were publishing interesting and accurate deductions—the only Spring which ought, which ever can guide the Pen of the Faithful Servant of Science, is a benevolent desire that others may participate in the advantages

which he thinks may be derived from his Discoveries: — and your True Philosopher is

> "Patient of Contradiction, as a Child
> Affable, Humble, Diffident, and Mild,
> Such was *Sir Isaac*, and such *Boyle* and *Locke*:
> Your Blund'rer is as sturdy as a rock;
> His still-refuted quirks he still repeats;
> New-raised objections with new quibbles meets;
> Till, sinking in the quicksand he defends,
> He dies disputing, and the Contest ends—
> But not the Mischiefs;—they, still left behind,
> Like Thistle-seeds, are sown by ev'ry wind."
>
> COWPER'S *Progress of Error.*

The Essays referred to above, are the productions of Members of the Royal Society — to which, they were presented by the President—were approved by the Council of 21, (chosen from the 500 F.R.S.) who form (see Preface to the *Phil. Trans.*) "the Committee who reconsider the papers read at the General Meetings, and select out of them such as they judge most proper for publication." Thus, sanctioned by the *imprimatur* of Half a Thousand *Sçavans*—and received into that Rich Treasury of Science, the *Philosophical Transactions*, they have been promulgated to the World in the most prepossessing manner.

Well then, Gentle Reader, perhaps you may think me a bold man, to dare to differ from doctrine published in a Work which is so universally and so justly esteemed, till you consider,—that I come to

this combat under the Banner of the Immortal NEWTON, and find, that the follower, like his Leader, is armed with the irresistible Spear of ITHURIEL.

The following is an extract from the *Phil. Trans.* for May 1672, at p. 4056 of vol. vii.

"Mr. ISAAC NEWTON'S *Considerations upon part of a Letter of Monsieur de Berce, printed in the Eighth French Memoire, concerning the cata-dioptrical Telescope, pretended to be Improved and Refined by* M. Cassegrain.

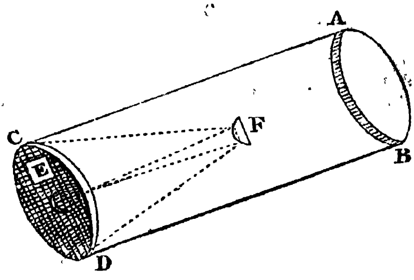
"*That the Reader may be enabled the better to judge of the whole by comparing together the contrivances both of Mr. Newton and Mr. Cassegrain; it will be necessary to borrow from the said French Memoire what is there said concerning them; which is as follows:*—

"I send you (saith *M. de Berce* to the Publisher of the Memoire) the Copy of the Letter which *M. Cassegrain* hath written to me concerning the proportions of *Sir Samuel Moreland's* Trumpet. And as for the Telescope of *Mr. Newton* it hath as much surprised me as the same Person, that hath found out the proportions of the Trumpet. For it is now about three months, that that person communicated to me the figure of a Telescope, which was almost like it, and which he had invented; but which I look upon as more witty. I shall here give you a description of it in short.

"A B C D is a strong Tube, in the bottom of which there is a great concave *Speculum*, C D, pierced in the middle, E.

"F is a convex *Speculum*, so disposed, as to its convexity, that it reflects the *Species*, which it receives from the great *Speculum*, towards the hole E, where is an Eye-glass, which one looketh through.

The advantage which I find in this Instrument above that of *Mr. Newton*, is, first, that the mouth or aperture, A B, of the Tube, may be of what bigness you please; and consequently you may have many more rays upon the Concave *Speculum*, than upon that of which you have given us the description. 2. The reflection of the rays will be very natural, since it will be made upon the *axis* itself, and therefore more vivid. 3. The vision of it will be so much the more pleasing, in that you shall not be incommoded by the great light, by reason of the bottom C D, which hideth the whole face. Besides that you'll have less difficulty in discovering the Objects, than in that of Mr. Newton's.



"*So far this French Author; to which we shall now subjoin the considerations of Mr. Newton, as we received them from him in a Letter written from Cambridge, May* 4, 1672, *as follows:—*

"Sir — I should be very glad to meet with any improvement of the Catadioptrical Telescope; but that design of it, which (as you inform me) *Mr. Cassegrain* hath communicated 3 months since, and is now printed in one of the French *Memoires,* I fear will not answer expectation. For, when I first applied myself to try the effects of Reflexions, *Mr. Gregory's Optica Promota* (printed in the year 1663) being fallen into my hands, where there is an Instrument (described p. 94,) like that of *Monsieur Cassegrain's,* with a hole in the midst of the Object-metal to transmit the Light to an Eye-glass placed behind it; I had thence an occasion of considering that sort of constructions, and found their disadvantages so great, that I saw it necessary, before I attempted any thing in the Practique, to alter the design of them, and place the Eye-glass at the side of the Tube rather than at the middle.

"The disadvantages you will understand by these particulars. 1. There will be more light lost in the metal by reflexion from the little *Convex Speculum,* than from the *Oval plane.* For it is an obvious observation, that Light is more copiously reflected from any substance when incident most obliquely.

"2d. The *Convex Speculum* will not reflect the

rays so truly as the oval plane, unless it be of an Hyperbolique figure; which is incomparably more difficult to forme than a plane; and if truly formed, yet would only reflect those rays truly, which respect the *axis*.

" 3d. The errours of the said Convex will be much augmented by the too great distance through which the rays, reflected from it, must pass before their arrival at the Eye-glass. For which reason I find it convenient to make the Tube no wider than is necessary, that the Eye-glass be placed as near to the oval plane as is possible, without obstructing any useful light in its passage to the object-metal.

" 4th. The errours of the Object-metal will be more augmented by reflexion from the Convex than from the Plane, because of the inclination or deflexion of the Convex on all sides from the points, on which every ray ought to be incident.

" 5th. For these reasons there is requisite an extraordinary exactness in the figure of the little Convex, whereas I find by experience that it is much more difficult to communicate an exact figure to such small pieces of Metal than to those that are greater.

" 6th. Because the errours at the perimeter of the Concave Object-metal, caused by the Sphericalness of its figure, are much augmented by the Convex, it will not with distinctness bear so large an aperture, as in the other construction.

"7th. By reason that the little Convex conduces very much to the magnifying virtue of the instrument, which the oval plane doth not, it will magnify much more in proportion to the sphere on which the great Concave is ground, than in the other design; and so magnifying Objects much more than it ought to do in proportion to its aperture, it must represent them very obscure and dark; and not only so, but also confused by reason of its being overcharged. Nor is there any convenient remedy for this. For if the little Convex be made of a larger Sphere, that will cause a greater inconvenience by intercepting too many of the best rayes; or if the Charge of the Eye-glass be made so much shallower as is necessary, the angle of vision will thereby become so little, that it will be very difficult and troublesome to find an object, and of that object, when found, there will be but a very small part seen at once.

"By this you may perceive, that the three advantages, which *Monsieur Cassegrain* propounds to himself, are rather disadvantages. For, according to his design, the Aperture of the Instrument will be but small, the Object dark and confused, and also difficult to be found. Nor do I see, why the reflexion is more upon the same *axis*, and so more natural in one case than in the other: since the *axis* itself is reflected towards the Eye by the Oval plain; and the Eye may be defended from external light as well at the side as at the bottom of the Tube.

"You see, therefore, that the advantages of this design are none, but the disadvantages so great and unavoidable, that I fear it will never be put in practice with good effect. And when I consider, by reason of its resemblance with other Telescopes, it is something more obvious than the other construction, I am apt to believe, that those who have attempted any thing in Catoptricks, have ever tryed it in the first place, and that their bad success in that attempt hath been the cause why nothing has been done in reflexions. For *Mr. Gregory*, speaking of these instruments in the aforesaid book, page 95, sayeth, *De mechanica horum speculorum et lentium, ab aliis frustrà tentatâ, ego in mechanicis minus versatus nihil dico.* So that there have been tryals made of these Telescopes, but yet in vain. And I am informed, that about 7 or 8 years since, *Mr. Gregory* himself, at *London*, caused one of six feet to be made by Mr. Reeve, which I take to have been according to the aforesaid design described in his book; because, though made by a skilful Artist, yet it was without success.

"I could wish, therefore, *Mr. Cassegrain* had tried his design before he divulged: but if, for further satisfaction, he please hereafter to try it, I believe the success will inform him, that such projects are of little moment till they be put in practice."

The Cassegranian Telescope has been highly commended by that celebrated Mathematical Instrument-

maker, Mr. JESSE RAMSDEN — in his Paper in the 69th vol. of the *Phil. Trans.* for 1779, p. 419, entitled, "A Description of Two New Micrometers,"— from which I have extracted the following:

"I believe it would more tend to the advancement of the art of working Mirrors, if writers on this subject, instead of giving us their methods of working *Imaginary Parabolas*, would demonstrate the properties of curves for mirrors which placed in a telescope will shew images of objects perfectly free from aberration; or, what will yet be more useful in practice, of what forms specula might be made, that the aberration caused by one mirror may be corrected by that of the other. If mathematicians assume *data* which really exist, they must see that when the two specula of a reflecting telescope are parabolas, they cause a very considerable aberration which is negative, that is to say, the focus of the extreme rays is longer than those of the middle ones. If the large speculum is a parabola, the small one ought to be an ellipse; but when the small speculum is spherical, which is generally the case in practice, if concave, the figure of the large speculum ought to be an hyperbola; if convex, the large speculum ought to be an ellipse, to free the telescope from aberration.

"This will be easier understood by attending to the positions of the first and second images; when a curve is of such form that lines drawn from each image, and meeting in any part of the curve, make

equal angles with the tangent to the curve at that point, it is evident that such curve will be free from aberration.

" This is the property of a circle when the radiant and image are in the same place; but when they recede from each other, of an ellipse, of such form that the radiant and image are in the two *foci* till one distance becoming infinite the ellipse changes into a parabola, and to an hyperbola when the focus is negative, that is to say, when reflected rays diverge, and the focus is on the opposite side of the mirror.

" These principles made me prefer CASSEGRAIN'S construction of the reflecting telescope to either the GREGORIAN or NEWTONIAN. In the former, errors caused by one speculum are diminished by those of the other.

" From a property of the reflecting telescope, (which has not been attended to,) that the apertures of the two specula are to each other very nearly in the proportion of their focal lengths, it follows, that their aberrations will be to each other in the same proportion, and these aberrations are in the same direction, if the two specula are both concave; or in contrary directions, if one speculum is concave, and the other convex.

" In the *Gregorian* construction, both specula being concave, the aberration at the second image will be the sum of the aberration of the two mirrors;

but in the CASSEGRAIN •construction, one mirror being concave, and the other convex, the aberration at the second image will be the difference between their aberrations. By assuming such proportions for the *foci* of the specula as are generally used in the reflecting telescope, which is about as 1 to 4, the aberration of the CASSEGRAIN construction will be to that in the GREGORIAN as 3 to 5.

" I have mentioned these circumstances in hopes of recommending the demonstration of curves suited to the purpose of Optics to the attention of mathematicians, which would be of great use to artists."—See *Phil. Trans.* for 1779, vol. lxix. p. 425 of Mr. J. Ramsden's Paper.

In page 206 of the 2d part of the *Phil. Trans.* for 1813, the reader will find CAPTAIN KATER'S Account of his Experiments for the purpose of ascertaining the relative Illuminating powers of CASSEGRANIAN and GREGORIAN Telescopes.

" From the first experiment it appears, that the light in both Telescopes, was equal, when the area of the aperture of *The Cassegranian*, was to that of *The Gregorian*, as 4.632 to 10.871.

" Now the increase of light being (under similar circumstances) directly as the area of the aperture, it follows that if the aperture of the Cassegranian be made equal to that of the Gregorian, the light in favour of the former will be as 10.871 to 4.632, or in the surprising proportion of 7 to 3 nearly."—p. 209.

CAPTAIN K. informs us, in page 211, that "a mean of the results of the several experiments was, that the light of a Telescope of the *Cassegranian* construction, may be taken, to that of a *Gregorian* of the same aperture and power, as about 60 to 33."

## MR. TULLEY'S LETTER.

*Experiments to ascertain the Comparative Difference of the Cassegranian and Gregorian Reflecting Telescopes.*

"THE extraordinary account of the great quantity of light reflected by the *Cassegranian* Construction, as asserted by CAPT. KATER (see *Phil. Trans.* for 1813 and 14), excited my attention, it having been heretofore considered that the only difference was the inverted position in which it shews objects.

"From the time of the Invention of Reflecting Telescopes to the present day, the *Newtonian* Construction has been justly considered to reflect more light than any other form of Reflecting Telescope, and it must be so, by reason that light is more copiously reflected from an inclined plane than when the rays fall perpendicular on the surface.

"The light reflected by a *Newtonian* Telescope, compared with a *Gregorian*, is very nearly equal, when their diameters are as 6 to 7, which difference is much less than what CAPT. KATER makes between the *Gregorian* and the *Cassegranian*: according to

his deductions the *Cassegranian* reflects more light than the *Newtonian*;—from the nature of the Construction, this is impossible,—and is it not improbable, that such a difference should remain so long unobserved, when so many ingenious opticians have been interested in the Improvement of Reflecting Telescopes ?

" Mr. JAMES SHORT spent upwards of 35 years on the *Gregorian* and *Cassegranian* Construction, and subsequent Opticians have spent the greater part of their days in similar pursuits, and the only improvement since SHORT's time is in the composition of the Speculums ; as Mr. Varley observes, in his account of Lord Stanhope's Telescope, ' to bring Telescopes to the perfection to which they are now brought, has exercised the patient industry and intellect of some of the greatest men that ever lived.'

" Mr. CRICKMORE made the Telescopes which CAPT. KATER made his Experiments with. CAPT. K. informs us that Mr. C. was a self-taught genius, and that his Telescopes were more perfect than any he has seen before.—I therefore conclude that CAPT. KATER has not had an opportunity of seeing any of the best Reflecting Telescopes that have been made,—if he has, he must have judged from Memory only, not from comparison; for a Reflecting Telescope is a simple instrument, and limited in perfection, and that perfection is attained, as many have been made as perfect as art can pro-

duce them; therefore, to improve it must require a new system and new materials, both of which at present are unknown. If Mr. Crickmore, with very little practice, has even equalled, much less surpassed, what has been done before, he has been very fortunate indeed.

" It is clear to me, that there has been some Error either in the Instruments or the Observations,—there is no such difference existing between the two forms.

" It is well known, that light and pencils of light will pass and repass each other in all directions. without suffering any loss in their course.

" Rays of light reflected from a concave mirror, or refracted through a convex lens, seem to diverge in a greater angle than they converged before they crossed, but in what proportion remains to be determined; and this greater divergency, it appears by the experiments of CAPT. KATER, he has taken for loss of light, which being less condensed will consequently appear less luminous: but when these more dispersed rays of light are made to return, as in the *Gregorian* Telescope, by means of the small speculum, they make the same angle, as they do from the small convex speculum in the *Cassegrain*, which returns the rays before they cross; that is, *when all the metals in both Telescopes are of equal radii, the light reflected will be the same.*

" I have caused two 2 feet Telescopes of this de-

scription to be made with the greatest care, and the magnifying powers and angle of vision, or field of view, is exactly the same in them both, and there does not appear one atom of difference; they seem to be as much alike as it is possible to make two things, except that of the Cassegrain shewing the object inverted, Dr. PEARSON, Dr. KELLY, and Mr. ARAGO, a French astronomer, all declared they could see no difference. — Since writing the above, I have had two Telescopes, that I made some years ago, in my possession, of the Gregorian form; they are 7 inches diameter, and 27 inches focal length, and very perfect: one of them is the Telescope I made for Dr. KITCHINER. I altered one of them into a *Cassegrain* with great care, and have compared them with equal magnifying powers, and at different times of the day; but *the best time to judge of the light of Telescopes*, is towards evening, about sunset, or a very little later, when I could plainly perceive a difference between a power of 77 and 82; whichever Telescope had the power of 77, compared with the other at 82, was very visibly the lightest: when the powers were equal, the light was equal also.

July 1817. "CHAS. TULLEY."

"DEAR SIR,

"THE above is an account of the Experiments I made with the *Gregorian* and *Cassegranian* Reflecting Telescopes, in order to ascertain the Comparative

difference as stated by CAPT. KATER—and I have the pleasure of sending it to you; and any information I am capable of giving, I will do it with pleasure.

"I am, Dear Sir,
"Your very obedient and humble Servant,
"CHA. TULLEY."

Islington, April 14, 1823.

"Mr. TULLEY constructed two pairs of telescopes, one of each pair a Gregorian, and the other a Cassegranian, so as to match each other exactly in dimensions, powers, and quality of the metals and glass, in order to ascertain if one construction has any advantage over the other in quantity of light, under exactly the same circumstances; and though several scientific gentlemen, besides the author of this article, have examined and compared different objects, as seen successively by each of the two telescopes of both pairs, yet not the least difference can be discerned by any observer. When the last glimmering of daylight remained, the vanishing object ceased to be visible with each like telescope at the same time, as nearly as could be ascertained; and that with both pairs, though they are constructed with dimensions greatly different the one pair from the other, and vary consequently in their powers and quantity of light. This experiment originated out of CAPTAIN KATER's paper on this subject, which was published in the *Philosophical Transactions* of London, in the year 1813; and we

have no hesitation in saying, that the quantity of illumination is the same in both constructions, when the dimensions and qualities of the constituent parts are perfectly similar. Whatever may be the dispersion of light at the point of crossing of the rays, in the Gregorian construction, when the dispersed rays are returned from the second speculum, they are collected again, it should seem, *without loss*, certainly without apparent diminution of light. This conviction we put on record, not out of a spirit of Controversy, but from a love of Truth."— See Dr. REES's *New Cyclopædia*, vol. XXXV. Art. *Telescope*.

MR. WATSON'S LETTER.

May 20th, 1824.

"SIR,

"IN the course of my 53 years' practice in making Reflecting Telescopes, I have had few opportunities of comparing the Gregorian and Cassegrain, but sufficient to convince me, that *the Cassegrain has no advantage over the Gregorian*, except its being a few inches shorter: it is very seldom asked for, as, the vision being inverted, it is only fit for Astronomical purposes.

"I have only made *One*, and seen *Another—Mr. Short's Dumpy*, when it was under the care of Mr. Dalby, Astronomer to the Honourable Topham Beauclerc; when a Gregorian of my making, of the same aperture and focal length, was compared with

it by Mr. Dalby, another gentleman, and myself, they both freely allowed the Gregorian to be much more brilliant and distinct than the Cassegrain.

" About the year 1794, I made the Dumpy* of 3 inches Aperture, and 6 inches focus, for Mr. Wm. Walker, the Lecturer on the Eidouranion, and which you purchased from him—this little Telescope had two sets of metals, one for the Gregorian, the other for the Cassegrain, and was equally good with each set; and we saw objects just as distinct and bright in the *Gregorian* as in the *Cassegrain;* and *Castor* appeared like a figure of 8 of fine outline, and the two stars round and sharply defined in the centres of it.

" The making of this Telescope discovered to me that the curve of the large metal most proper for the Gregorian, is not so for the Cassegrain, which requires a different figure.

" I therefore made another large metal, and gave it such a figure, as, combined with the convex small metal, gave distinct vision. This little Cassegrain had three convex small metals, and magnified from 75 to 400 times.

" In the year 1780, I made a Newtonian for the late Mr. Jesse Ramsden, which was of 8 feet focus, and the large metal 10 inches diameter—with this

* When Mr. Watson made this Dumpy Cassegrain for Mr. Walker, he was in the zenith of his powers as a Telescope-maker—as when he wrote this letter he was in the fulness of his age and experience, having just completed his 78th year.

Telescope the division of the Ring of Saturn, his Belts, and the shadow of the ball, cast on the Ring—the shadows of Jupiter's Moons on the disk of that planet, his Belts, and the termination of his disk—were all seen, most beautifully defined. This Telescope was, from its large dimensions, and powerful effect, the finest Telescope I ever saw.

"There is certainly more light reflected by a Newtonian than by either a Gregorian or a Cassegrain Telescope.

"J. WATSON."

To WM. KITCHINER, M.D.

22 Bishop's Walk, Lambeth,
24th May, 1824.

"DEAR SIR,

"HAVING seen in a publication some time back, an account of experiments made with Cassegrain and Gregorian Telescopes, to ascertain which construction had the superiority of light, and that the result was in favour of the former, I was led to doubt the accuracy of the observations from the means employed, namely, with two Telescopes by different makers, and, of course, the materials of different reflecting qualities, it must be obvious, that unless the materials in each Instrument were precisely of the same casting, no certain result could be obtained.

"I had but little doubt on the subject, but never having made the experiment, I cast two small speculums, a concave and a convex, of the same material, and ground them to the same curve. I applied them to a Telescope I was making at the time—I tried the Instruments on a dial of a watch, on the evening of a fine day, when the light was gradually decreasing, by repeatedly shifting the small speculum, till the light of the evening was so far decreased that I could only discover the white spot the dial formed; but could not discover any superiority of light in the two constructions.

"The only advantage I know in the Cassegrain over the Gregorian, is the reduction of length about 4 inches in a 2 feet Telescope; and that advantage is more than counterbalanced by the objects being inverted. For Celestial purposes, it would be of little consequence; but for Terrestrial, the disadvantage must be obvious to every one.

"I discovered in the course of my experiments, that the curve of the large speculum best for the Gregorian construction, did not answer equally well for the Cassegrain; but being satisfied no superiority of light was to be obtained by the Cassegrain, I did not carry my experiments further. It is my intention to make further experiments to ascertain the difference of curves required to produce distinct Vision, with the three constructions, namely, Newtonian, Gregorian, and Cassegrain Telescopes;

the results of which I shall feel great pleasure in communicating to you as soon as made; and remain, Sir,

"Yours respectfully and obliged,

"JOHN CUTHBERT."

To Dr. KITCHINER, &c.

In the course of the last 30 years, I have seen the following Cassegranian Telescopes—*Short's* Dumpy, 2 feet long, 6 inches diameter—*Watson's* Dumpy, 7½ inches long, 3 inches diameter—a 30 inch of 6 inches Aperture, made by Mr. Tulley, for Mr. Custans, which was afterwards in Mr. Wm. Walker's Observatory.

The Trial Telescope which Mr. Tulley made for Mr. Hodgson, was $5\frac{3}{10}$ths inches Aperture, and 30 inches long—and had one set of Cassegranian and another set of Gregorian metals.

Mr. Hodgson's Observations on their performance, which I found in the case of the Telescope, are

| GREGORIAN. | | CASSEGRANIAN | |
|---|---|---|---|
| 70 | good | 80 | middling. |
| 100 | good | 120 | very dull |
| 126 | good | 200 | very dull |
| 200 | middling | 320 | very dull |

From which it may be fairly inferred, taking it for granted that the two Telescopes were equally per-

fect—that the diminution of light occasioned by the small increase of the magnifying power of the Cassegranian metals, induced him to imagine the Gregorian was *good*, while the Cassegranian was only *middling*, or *very dull*—for Mr. Tulley has assured me, that the vision was equally sharp with each set of speculums. I tried the Gregorian set against a very fine 5 feet Achromatic, of $3\frac{8}{10}$ths inches aperture, and with equal powers it shewed a printed Paper better than the Achromatic.—See Chapter on *Illuminating Power*.

Mr. George Hodgson, F.R.S., built an Observatory at Hoddesdon, Herts. He was a very ingenious person, and purchased the Instruments for his Observatory without any regard to the cost of them—and had the following Telescopes—therefore had sufficient means to judge of the comparative powers of various Instruments.

*A Newtonian, by Sir Wm. Herschel, 7 feet focus, $6\frac{3}{10}$ths diameter.
*An Achromatic, the favourite Telescope of the
late Mr. Peter Dollond, 5 feet focus ........ $3\frac{8}{10}$ths ——
*Ditto 46 Inches, the favourite of Mr. A. Aubert,
by Mr. Peter Dollond .................... $3\frac{6}{10}$ths ——
*Ditto 45 Inches, the favourite of Wm. Larkins,
Esq. by Mr. Peter Dollond .............. $2\frac{7}{10}$ths ——
*A 30 Inch Achromatic, by Mr. G. Dollond .. $2\frac{7}{10}$ths ——

* Those marked with* were purchased by the Author of this work.

| | |
|---|---|
| A 30 Inch Cassegranian and Gregorian, above mentioned............................ | $5\frac{3}{10}$ths diameter. |
| A 5 feet Newtonian, by Mr. Tulley .......... | 5 ——— |
| A 46 Inch Achromatic, by Mr. Tulley ........ | $3\frac{6}{10}$ths ——— |

And half-a-dozen other Telescopes, &c.

His Instruments were sold by Mr. S. Sotheby, in March 1824.

It has been said by several Practical Opticians, that that curve of the Large Speculum which may be most perfect for a Gregorian with a *Concave* Small Speculum—will not be so proper for a Cassegranian with a *Convex* Small Speculum. I cannot understand why that figure which performs well with the *Concave* should not act as well with the *Convex*. An Object-Glass, or Newtonian Telescope, which is distinct with a *Convex*, is equally distinct with a *Concave* Lens.

" An experienced Telescope-maker told me, that during the time that it was the fashion to admire the Illuminating power of the *Cassegranian* Telescope — he made a *Cassegranian* convex small Speculum, and fixed it on the same arm, on the back of the *Concave;* and it was equally distinct with the *Concave,* and equally light: and the experiments which he then made perfectly satisfied him, that a Gregorian Telescope is as light as a Cassegranian." This, if the Reader has a Gregorian Telescope, he may see for himself, by getting a

*Convex* small metal, of the same magnifying power as the *Concave*, which he may procure for a Guinea.

As honest ISAAC NEWTON wrote in page 500 of vol. x. of the *Phil. Trans.*—" This is to be decided not by Discourse, but by a new trial of the Experiments."

## CHAPTER X.

### HOW TO ADJUST, OR SET A TELESCOPE, AND OF THE FIELD OF VIEW.

FROM the want of knowing how to adjust a Telescope to distinct Vision for different Distances, I have not been much surprised when I have heard some people complain most clamorously, that they never met with a Glass through which they could see distinctly; and others, that their Eye is always so strained by looking through a Telescope that they are afraid to use one.

However, to look through a good Glass when it is accurately Adjusted, I believe is very little, if any, more fatigue to the Eye, than it is to look with as earnest attention, at the same Object, for the same length of time with the naked Eye.

It should be explained to those who have not been accustomed to use Telescopes, that if every part of the Instrument is perfect, and perfectly clean — that if objects do not appear perfectly distinct, and sharply defined, that fault must arise either from the various parts of the Telescope not being properly adjusted to each other, or to the Instrument not being adjusted to the Eye of the person observing.

*Each person ought to set a Telescope for his own Eye,* for almost every Eye, even of people of the same age, has its peculiar focus.

Persons unaccustomed to adjust a Telescope, are often unable to do so with that degree of nicety which is needful to produce perfectly distinct vision: and it is extremely difficult for another person to do so for them, however well acquainted with the usual peculiarities of the Eye at various Ages:—thus the most interesting parts of Telescopic Exhibitions are often seen but very imperfectly.

To give some idea of *the Focus,* Opticians sometimes draw a line round the Tube, where the Telescope is most distinct for a Common Eye at the distance commonly required.

As the Reader may have observed, that the Spying Glasses which are in use at Watering Places — and at Sea — have a mark on their tube which is called *the place to set it to*—very few persons have any idea that every variation in the distance of the Object, or the Age of the person, requires a variation of the adjustment of the Glass.

*When You use a Telescope,* — hold the Outer tube in one hand, and the Inner with the other hand— *look through the centre of the Glass at the Object you wish it to shew you, and* ADJUST IT patiently and precisely: — thus, — press the Eye-tube towards the Object-Glass, Vision will gradually increase in distinctness as the Eye-Glass approaches its proper

distance from the Object-Glass, and when there, the Object will be seen perfectly and sharply defined — if the Eye-tube be put in beyond the proper distance, the object will again become indistinct, and in that case, the Eye-tube must be withdrawn again :—a very little practice, will enable a person easily to obtain the precise point at which the most perfect distinctness can be obtained. — This is a much better way of adjusting a Glass than to put it up to the Eye, and then pull out the Inner tube— by which act, if the tube does not slide regularly, or is shorter than you expect, it may suddenly slip out, and strike your Eye, and plant a Cataract.

The greater the Magnifying power of a Glass, the greater nicety is required in adjusting it.

*If You wish to see any thing further off, or nearer,* — for each variation of distance, a corresponding variation of ADJUSTMENT is required ; *i. e.* of the distance of the Eye-piece from the Object-Glass—which must be diminished, in the proportion that the distance of the Object is increased. This caution is quite necessary.—I have met with many persons who have condemned a Glass because they could only see some objects distinctly with it, and for others they found it useless — merely, because they had not been told, that — *every variation of the Distance of the Object, requires a corresponding variation in the* ADJUSTMENT.

More Glasses have been condemned for the want

of this knowledge than from any other cause — and more Eye and Object-Glasses have been spoiled. Those who are not aware of it suppose that when they turn their Glass to an Object to which it is not adjusted that its Glasses want wiping, and they keep rubbing, till in a little time they render them about as unfit to look through as Ground Glass.

Sometimes *a Film or Fog forms between the Object-Glasses,* or, as the Optical phrase is, " the Glasses sweat :"—when this happens, they must be taken out of their cell and wiped with a bit of soft Leather or of very fine Silver Paper—but never do this but when it is absolutely needful, and then take care to replace them in the same position; it is seldom requisite oftener than once or twice in a Year. Nor wipe the Object or Eye-Glass except they really require it—as often as you wipe them—you scratch them a little.

To See an Object distinctly at any given distance. *The longer and older the Sight of the Person,* the longer the tube must be drawn out—Thus—if a person of 20 years of Age, who has *a common Eye,* has adjusted a Glass, for distinct vision at the distance of 60 yards — and wishes to set it so that a person of 40 or 50 years of Age, who uses Convex Spectacles of 36 or 30 Inches focus, may see as distinctly with it an object at the distance of 60 yards — he must pull out the tube about the eighth of an Inch further, — more or less, as the Eye is

longer or older, the Telescope is longer or shorter: and the Magnifying power, and the distance of the Object, are more or less,—or they must look through the Glass with their Spectacles on.

*Near-sighted People,* when they wear their Spectacles, See at the same focus as persons who have a common eye—*without their Spectacles* the tube must be pushed in nearer to the Object-Glass.

*The best way of holding a Glass.*

If you put it up to your Right Eye, hold it with your Left Hand—in such a manner, that the Left Arm forms a blind before the Left Eye.

Some Fidgety folks, when not looking through their Glass, keep ever and anon, pawing, and *wiping the Eye or the Object-Glass;*—neither of these should be touched,—except when it is absolutely necessary to clean them, and then, only with a bit of soft Leather, fine Linen, or the finest Silver Paper.

*The Sliding Tube* soon becomes dirtied by the dampness of the hands;—to avoid this, *do not touch the Sliding Tube,* but take hold only of the Neck of the Eye-head, and adjust by that. *The Sliding tube must be wiped occasionally,* so that it may slide smoothly—if it will move only by fits and starts, you will not be able to adjust it accurately.

I have heard persons (unacquainted with the

Laws of Optics,) complain, that a Glass magnifying 40 times, has not so large a *Field of View* as a Glass which magnifies only 20—this cannot be remedied;—their only alternative, is to have a small Field distinct, or a large Field of little or no use—with a power of 40 they have in quality, what with 20 they have in quantity, and the objects which they do see, they see much more than twice as distinctly.

When a Telescope magnifies more than 100, it is as difficult as it is desirable to keep an object exactly in the middle of the Field at the same time that we are adjusting the Vision. Few Eye-pieces are so constructed that the field is so flat, that the Vision is good in the centre when the telescope is adjusted, while the object appears in the side of the field; and therefore, persons who are not particular in keeping the object in the middle of the field, get a notion that every telescope has some peculiar part of the field more distinct—this is merely because they adjusted the instrument while the Object was in that part, or the Instrument is out of Adjustment, or defective, and the errors of the Eye-glasses correct those of the Object-Glass in certain parts of the Field.

All good Telescopes that are in good adjustment, are most distinct in the central point—those which appear otherwise only appear so because they have

not been properly adjusted when the object was exactly in the centre of the field.—See *Clock-Work Equatorial Motion*, in Index.

*For large Adjustments*, and that the Telescope may be used for near objects, (and occasionally do the business of a MICROSCOPE*,) it should have a *Sliding Tail-piece;* — and the Tooth and Pinion for *the fine Adjustment* must be finished very carefully, so as to move easily and smoothly, or it will shake the Glass while adjusting it.

The Machinery for adjusting the focus, may be as much too fine—as too coarse.—The fine *Screw* adjustment, which still seems the best that can be applied to Gregorian Reflectors, was applied to the original 46 Inch Achromatics — but when even a power of 150 is applied to them it is not quick enough, and the focal point is not half so easily and exactly hit, as with the *Tooth and Pinion* adjustment on the side of the Tube.

A badly finished *Adjusting Screw* is one of those defects, we must expect to find, in Instruments, which are so very rarely used by those who make them—the workman is not aware, how indispensable

* A former writer has observed, that a Spider at work is a curious object for such a Microscope, adding that you may observe his proceedings at such a distance—that the ingenious insect will not be in the least disturbed, nor have the least idea that you are watching his Web-making!

it is, that the Telescope be perfectly steady during the adjustment of the focus.

There should be two *Steadying sliding Tubes* applied from the eye-end of the telescope to the stand. These will greatly diminish the tremour, which is such an impediment to Vision.

When the Eye is perfectly satisfied with the adjustment of the focus, let the Telescope be so placed that the object may pass through the field, the Instrument remaining at rest during the time :—this answers better than tottering after it with Rackwork.

*Very remote Terrestrial objects* are best seen about an hour or two after Sun-rise—or an hour or two before Sun-set. When I was at Brighthelmstone some years ago, I could, in the early part of the Morning and Evening, very easily see the Isle of Wight; which, in the intervening hours of the day was hardly perceivable.

Telescopes act best when used in the same direction that the Sun Shines. Mr. VARLEY observes, " I have known Good Telescopes condemned by trying them upon objects situated towards the East in the morning, the South at midday, or the West in the evening."

### OF THE FIELD OF VIEW.

The field of view in Telescopes constructed with *Convex Eye-glasses,—is* (regulated by the Stop which

is placed in the focus of the 1st Eye-glass, or that next to the Eye;—the diameter of the Stop is regulated by the diameter of the 2d Eye-glass, the diameter of which varies) *according to the Magnifying power used.* If the Stop be opened larger than the 2d E. G. it will produce a strong Orange Colour around a very indistinct margin.

*The Apparent Field* may be easily ascertained by measuring the number of degrees contained in the space taken in by the Telescope when directed to the heavens, or to some very distant objects. Thus, as the apparent field of *the Full Moon* is about half a degree, if the Telescope only take in the Moon, we say its field is half a degree; and "cæteris paribus" the field of view becomes smaller as the magnifying power becomes larger. *The distance between the two pointers of the Great Bear* is nearly five degrees. I mention this, to help the eye to estimate distances in the heavens.

*With the same Magnifying power, the field of view is the same,* whether the Aperture of the Telescope be *One* Inch, or *Three*. This is easily proved, by contracting the Aperture of a *Three* Inch Telescope to *One* Inch, when the field of view will remain the same;—you will find that the only difference in its appearance, is the diminution of the brightness of it.

But with Perspectives or Galilean Telescopes,

or Opera Glasses which have a *Concave Eye-glass*—*The Field of View, when they do not magnify more than Twice, depends in a great measure on the Diameter of the Object-Glass.*

## CHAPTER XI.

HINTS FOR SHEWING CELESTIAL OBJECTS TO PERSONS WHO HAVE NEVER SEEN THEM BEFORE; AND OBSERVATIONS ON THE IMPORTANCE OF THE PORTRAITS OF THE PLANETS, AND THE DIAGRAMS OF DOUBLE STARS.

THE Editors of former Optical and Astronomical works seem not to have been sufficiently sensible of the importance of presenting to the Eye accurate Portraits of the subjects of the Astronomer's contemplation.

Nature has given Eyes to all, an Understanding to few. Ocular demonstration is not only more desirable *per se*, but is more generally comprehensible than description; in the *ratio*, that more men can see than can reason.

However, it does not appear to me that any of the representations of the Moon or Planets given in former publications have been taken from Nature—(excepting Russell's moon, and Dr. Herschel's prints, in the *Phil. Trans.*): the *Moons* are miserable imitations of Hevelius's or Cassini's; and the only drawings of *Saturn* that in anywise resemble the

Planet, are bad copies of that made with Mr. Hadley's Newtonian Reflector in 1723; or those given by Huygens in his *Systema Saturnium*, 4to. 1569, in page 16 of which work he has given a drawing of the Planet without its Ring, as it appeared on Jan. 16, 1656; in p. 18, the reappearance of the Ring—and in pp. 21 and 24, two figures, which latter are such good representations of Saturn, I am surprised to find neither Belts nor Division in the Ring depicted, which I think must have been visible to him, if he saw the Planet as large as his print, and as well defined; in p. 35 are the 13 monstrous strange pictures of Saturn—which are copied in Dr. Smith's Optics, &c.; and in p. 55 is the drawing of the phases of the Ring, which has been copied into most of the elementary works on Astronomy.

Most of the other Portraits of the Planet, &c. are about as much like the Originals, as the sign of "*The Seven Stars*" on the alehouse at Brentford Butts is like the *Pleiades*.

The pictures of the Planets heretofore given in Astronomical works, seem to have been painted by the Imagination, rather than with the Eye, and remind one of the productions of some of the primitive Painters, who, with a modest consciousness of their lack of ability in their Art, or the want of discrimination in the Spectators, wrote under their Pictures, "This is done for a *Black Lion*;" or, "This is

a *White Cat;*" and instead of the Picture illustrating the press, the latter was employed to explain the former.

I consider it the chief merit of a Print that it is an accurate representation of the actual appearance of the Planet as seen in a powerful Telescope.

The engraving of *Saturn,* represents that Planet as it appeared in 1824, through my Herschel 7 feet Newtonian, with $6\frac{3}{10}$ths inches aperture, and an Huygenian Eye-piece magnifying 213 times — and in a 5 feet Achromatic, of $3\frac{8}{10}$ths aperture, magnifying 190 times; — and I trust will be acceptable to those who have not an Instrument of sufficient perfection and dimension to shew the Original.

It is sometimes no easy matter to make a Novice see either *the Belts of Jupiter*—or *the Belt on the Body and the Division in the Ring of Saturn,* the separation of *Double Stars,* &c., it is difficult to imagine what appearances are described by those Words—but when they have been pointed out in a Portrait of them, I have found people discern them directly—and candidly declare, that they knew not before what they were to look for. " It is much easier to see an object when it is pointed out to us, than when it falls in our way unexpectedly, especially when of such a nature as to require some attention to be seen at all."—Dr. HERSCHEL, in *Phil. Trans.* for 1782.

Therefore, those who wish to entertain their Friends with exhibiting to them these Celestial Phenomena—should first clearly explain to them, what they are to see, by shewing them a Portrait of the Object,—then, give them a general view of it with a low power of 60 or 80, which having a large field will allow the Planet to remain in view for a couple of minutes—and then refer again to the Portrait of it:—when thus prepared, the Exhibitor may proceed to apply such Magnifying powers as are best suited to the size of the Telescope and the nature of the Object to be observed.

A mode of calculating the due degree of Magnifying power for each Telescope and each object, I shall, in the following pages, I hope, succeed in explaining in the clearest manner.

*A Telescope for shewing other Persons,* should have for a Finder a one foot Achromatic with a power of 15 times, with several cross wires; this should stand out so far from the Telescope that One Person may conveniently look through it, while another is observing through the Telescope; and by means of Rackwork the person looking through the Finder may easily keep the object in the field of the Telescope, provided it does not magnify more than 130 times; almost as convenient a mode of observing with a common Finder may be produced by fixing before the Eye-tube a plain small

speculum set in an angle of 45 degrees—or any of the diagonal Eye-tubes.

It is extremely tiresome and fatiguing to the Eye to be continually finding objects for People who are unacquainted how to keep them in the field when they have got them; and no Object should be shewn to such folk that requires more than 130 times to render it plainly visible.

When a Telescope magnifies 130, the objects pass the field very rapidly; that is, in my 5 feet Achromatic, with the Huygenian Eye-piece, which magnifies 130 times, in 1 minute and 30 seconds — and the objects are perfectly distinct only during ⅔ds of that time, as the Margin of that Field is seldom distinct with the same adjustment as is requisite for the Middle of the Field.

Appointments to view Celestial Bodies are seldom kept punctually by Terrestrial Bodies. The Exhibitor is expected to stay at home whether the night be fair or foul — the Invited tell him when they see him, perchance a month after—"Well, friend Astronomer, I thought you would not expect us — the weather was so exquisitely uncertain!" Now, if the Sky had cleared up during any half-hour in the Evening, these selfish triflers would have cried out for Ever and Aye, if they had come and not found their Showman at home — therefore, always make a positive Bargain, that, hit or miss, whether Fine or Foggy, You come here at such an hour if you expect

Me to stay at home,—is it not clear enough to the humblest capacity, that it is merely common Good Manners, if you expect me to entertain You if it is Fine — that you should come and amuse me (if you can) if it is Foggy. Tell all who purpose to visit your Observatory that these are the conditions. Those Planet-struck persons who do not comprehend the Equity of this doctrine are better without your Doors than within them. You will certainly not suffer any such Ill-bred Idlers to play you such a trick Twice, unless They have a much larger stock of Impudence than you have of Understanding.

# CHAPTER XII.

## HOW TO CHOOSE AND HOW TO USE THE MAGNIFYING POWERS FOR DAY TELESCOPES.

THE degree in which Magnifying Power may be applied, depends on the Dimensions and the Defining Power of the Telescope, on the Distance of the Object, the degree in which it is illuminated, and the state of the Atmosphere: it is, therefore, very difficult to fix precise limits to it by General Rules.

To afford an opportunity of trying many entertaining experiments, the Day Eye-tube of an Achromatic Telescope should have a *Pipe-Drawer.*—See Index.

The Screw which receives the tube that contains the two first Glasses should be the same as the screw which is at the Eye-end of the Telescope.

The Two first Eye-glasses should be fitted into a sliding tube within the Pipe-drawer—which by separating from the 3d and 4th Eye-glasses will increase the Magnifying power $\frac{2}{3}$ds—thus, if the power is 30 when the tube is shut in, when pulled out to its extreme separation it will be 50.—See p. 32.

All Day Eye-tubes, especially of the Sliding Telescopes, which are called Military Telescopes, should

be thus constructed — the additional Expense or the Weight of the inner brass tube is a mere trifle—this is an extremely convenient contrivance, as it enables you to obtain the exact degree of Magnifying power adapted to the state of the Atmosphere, and the nature and distance of the Object — and serves the purpose of several Eye-pieces.—Read the Chapter on *The Pancratic Eye-Tube.*

The most regular, and most satisfactory manner of arranging the Magnifying Powers of Telescopes, would be in the order of the Diameters of the Pencil of Rays transmitted by them, beginning at $\frac{2}{10}$ths of an Inch for a Night-glass, &c., and proceeding to $\frac{1}{40}$th of an Inch for very bright Day Objects and Planets.

The Magnifying Power which is given by reducing the diameter of the Object-glass into Tenths of Inches, and multiplying that by Two, is the power usually put to *the ordinary Day Eye-tube of an Achromatic Telescope*—and with this, You will have all the advantage that Illuminating power can give, that is to say, as low a Power as is wanted for any purpose except a Night-glass, by reducing the aperture of a 30 Inch Achromatic, which is usually 2 inches, into tenths, which gives 20 for the Magnifying power :— multiplying that by 2 will give the power usually applied to such a Telescope for Day purposes—that is, 40 for a 30 Inch with an aperture of 2 inches—and

54 in a 3½ feet, with an aperture of $2\frac{7}{10}$ths inches, the diameter of the Pencil of Rays will then be the twentieth of an inch—multiply by 3, and you will have a high power for clear days,—by 4, and you will have, in a 30 Inch Telescope, of 2 inches aperture, a power of 80 and a pencil of the 40th of an inch in diameter, which is as small, and the Magnifying power as large, as the Illuminating power of the Object-glass will bear for Day purposes, except in extraordinarily fine Clear days, and on Objects which are uncommonly well lighted up. (See page 206.) I have used 150 with an aperture of $2\frac{7}{10}$ths inches, with great advantage, when a mile or two from the suburbs of the City:—it is astonishing how very much more transparent the Air is only half a mile from the borders of London; so much so, that a Telescope will act in an incredibly superior manner!—methinks I hear the Reader sigh, to think *what hard work the Lungs of our good Londoners have to perform, to extract Vital air from such a mass of Vapours!*

The Extent of Vision is limited by the myriads of heterogeneous particles which are constantly floating in the Atmosphere, these form a kind of veil which obscures distant objects, and the more the atmospheric medium is loaded with these particles,—the more a Telescope magnifies,—the more distant the Object from it—and the nearer it is to the horizon, the more obscure and indistinct becomes the Vision,

*For determining the sharpness of Day Telescopes*, try them at objects not more than a hundred Yards distant;—at an object half a mile distant, in many days of the Year you can hardly tell a good Glass from an indifferent one.

The exhalations which continually arise from the Earth augment the above-mentioned impediments, and render the air less transparent, especially near the horizon: but the obscurity arising from the exhalations is not the least part of the inconvenience which they occasion; they have an undulating motion like that of smoke or steam, so that objects seen through them, appear to have a tremulous or dancing motion, which is sometimes sensible even to the naked Eye.

If Distant objects are viewed on a hot Summer's day, this impediment to vision is sometimes so strong, as to render Telescopes entirely useless for Terrestrial purposes when they magnify more than 60 or 70 times.

These Obstacles often prevent our using Large Instruments and Large Magnifying powers with any thing like that advantage, which those who are unacquainted with these things, imagine that they may be employed:—for views of more than two miles distant, and for half the days in a year, an Achromatic of Two inches aperture, or a Gregorian of Four, will do almost as much as any larger Telescope.—See a particular account of a 2 *feet Gregorian Telescope* in p. 117 of Chapter VII. on *Reflectors*.

We should never use a higher Magnifier than we absolutely want; — the lower the Power, the more beautiful and brilliant the Object appears: — the field of view is proportionately large, more uniformly good and distinct, — and the motion of the objects passing it proportionately less: — thus they may be observed with greater ease and quiet attention. — See an account of *the time which a Celestial Object is passing through the field of Eye-tubes of* different magnifying power, p. 47.

There is no use in the pencil of rays being of larger diameter than the Optic pupil; this varies in magnitude, according to the brightness of the object presented to it, from One to at least Two-Tenths of an Inch. — See the Frontispiece to the First Part of the *Economy of the Eyes*.

When the light is too strong, or the Object is too bright, the Pupil instinctively contracts to intercept that excess of light which would otherwise offend the eye: — when the Light is faint, the Pupil expands, that a greater quantity of light may enter the Eye, and thus make a stronger impression upon it. *This contraction and dilatation of the Pupil* may be observed by holding a looking-glass, (or, what is still better, the lowest small speculum of a Gregorian telescope,) before your Eye at a window, and turning gradually from it, continually looking at the Eye. It may be more easily and perfectly seen by attentively watching the eye of another, during such a

change of position: I think it is most agreeably observed in a fine full bright Blue Eye.

*Ordinary Portable Achromatic Telescopes* (see p. 24,) are often charged with so low a power for Terrestrial purposes, that they are rather calculated for Night-glasses, than Day telescopes; this is done to suit the convenience of common purposes, and because they are mostly used without a stand, without which a higher power would be useless:—if the Object-glass be good, they will carry at least one-third more power than they are commonly charged with. When I read this remark to an Optician, he said, "Yes, that is all right if the instrument was to be used on a Stand; and by a person in the habit of adjusting a Telescope, otherwise, the absolute necessity of the positive focus being found, would be, to common untaught Eyes, a difficulty they would not so easily overcome."

The magnifying powers affixed to the above-mentioned Telescopes, in the 7th column of the *Table of Achromatics,* (see p. 24,) are those they are usually charged with.

If they are fine Instruments, they will bear much higher powers: and all Portable Sliding Telescopes should have a Separating Eye-tube or a *Pancratic*;—but it requires some practice, and a steady hand, to use higher Magnifiers with advantage, the tremours of the hand and the body being magnified in proportion to the Magnifying power; so that persons who are not accustomed to use a Telescope, even with

the common powers, complain of great difficulty either in finding or keeping an object in the field of view.

A Walking-stick, introduced into the waistcoat pocket, is *a good steadying Staff*.

Opticians have constructed various very steady, and

PORTABLE AND FOLDING STANDS,

some of which double together into the form of a Walking Stick.

A Stand is always a desirable, indeed an indispensable, apparatus, if you wish to shew an object to another person.—Stands must be steady in proportion to the Magnifying power employed.

Brass and other stands are now made so very light and portable, they are most desirable companions to a Telescope.

My favourite Portable Stand was contrived for me by that ingenious and excellent Workman, Mr. PRICE, *of Fetter Lane, Fleet Street*—it has a rising pillar, with a collar and clip at the top to fix it firmly at any height—a hinge to the clip which is screwed, not soldered on; a Finger Screw to regulate the tightness of the Vertical motion, and it may be detached from the Brass Legs and put into a Tripod, which folds in the form of a Walking Stick.

Care should be taken to fix a Telescope on the Stand in the centre of Gravity, and that it is balanced as evenly as possible when the Cap of the Object-end is off.

It will very much assist the Eye to wear a kind of goggle, big enough to go over the Eye-piece, to defend the organ of vision from the intrusion of collateral rays, which, without such a shield, distract and strain the sight, and prevent the perfect adjustment of the Eye, by its receiving the stimulus of surrounding objects and light,—at the time its whole attention should be confined to the pencil of rays from the Telescope; this may be made either of Leather, or Black Silk stiffened with varnish — and may be very easily attached either to the Eye-head or to a Spectacle frame.

THE EYE-HEAD

should be of Black Ivory, not less than an inch and $\frac{3}{8}$ths in diameter, and made Concave something in the form of an Eye-bath — or a semicone forming a shade on the side similar to those prefixed to the Tubes used for viewing Pictures—so that it may form a Screen around the Eye, and prevent the intrusion of any rays upon the retina, except those coming directly from the Glass — this will not only improve the Vision very much, but render it much easier to the Eye, which cannot adjust itself perfectly, while it is exposed to the stimulus of surrounding Objects.

Such defence from the intrusion of collateral rays will prevent the picture on the retina being confused by those adventitious rays which otherwise

distract it; if only those rays are admitted into the Eye which come direct from the object under examination, it will make a more vivid impression on the Sight, which will be sharpened and strengthened very much.

This is worthy the attention of all who wish their Eyes to enjoy the utmost sensibility that they are capable of being excited to — because,

The action of the Eye, like the action of a Telescope, is perfect, in the proportion that its adjustment is perfect, when all its attention is concentrated on one object, the sensibility of the Sight is much increased; — moreover, you will not only see better, but Vision being rendered easier, your Eyes may be employed longer, with less fatigue.

The Eye will be sensible of this assistance in the Daytime, but more especially when observing Planets or Stars on Moonlight nights.—See *Dewcap* and *Black Hood*, in the Index.

## CHAPTER XIII.

THE

# PANCRATIC EYE-TUBE,

INVENTED BY

WILLIAM KITCHINER, M.D.

*Is applicable to* ACHROMATIC* *and* REFLECTING TELESCOPES *of all Lengths, and also to* MICROSCOPES.

THIS EYE-TUBE is applied to the Telescope in the same manner as other Eye-tubes, and is adjusted to distinct Vision by the same Pinion motion.

For the *Lowest* Magnifying power, the Three Inner tubes must be shut up within the Outer one;— when the Magnifying power is to be increased, the smallest of the sliding tubes, A, must be drawn out to either of the numbers engraved upon it; care being taken not to draw out any part of the other sliding tubes, B and C, until the whole of *the First*, A, is pulled out; —*the Second* tube, B, may then be drawn out to either of the numbers engraven thereon; and in like manner *the Third* tube.

* Those in which the Errors arising from Colorific refraction, are corrected by the figure, position, and refractive power of the Lenses which constitute the Object-glass.

The numbers engraved on the Tubes, denote the Magnifying power of the Telescope.

† *To change the Power* for any less power than the one to which the tubes have been drawn out, the reverse of the above-described mode of proceeding must be observed; — the largest tube must be returned first, and so on, until they have been brought back to the number required.

*Each alteration of the Magnifying power* will require a new adjustment of the Pinion; — as the Magnifying power is increased, the distance between the Eye-glass and the Object-glass must be diminished.

" It has long been known, that the Magnifying powers of Telescopes could be augmented by increasing the distance between the two glasses next to the Eye, and the two that are next to the Object-glass, to *almost* double the power of the Eye-tube in its usual form, *i. e.* from 30 to 55. *This is the utmost that Opticians have heretofore accomplished;* — yet this variation is so desirable, that I think it only requires to be generally known, to be generally desired, both for Convenience and Cheapness*.

" A few months ago, I saw an Eye-tube, made

* Before Mr. JESSE RAMSDEN invented, about 1785, *The Pipe-Drawer* for the Terrestrial Eye-tube of an Achromatic — and changed the Magnifying power, by changing the two Glasses next to the Eye—for which half Eye-tube he charged half a Guinea — for every change of Magnifying power, there was the incumbrance and expense of another Eye-tube, costing £1. 1s.

by Mr. CAUCHOIX, with a scale of magnifying powers from 25 to 73; but, upon trial, I found that the vision was perfectly good only between 35 and 45.

"My attention was strongly excited by the idea of ONE Eye-tube effecting the whole business of Magnifying; and after several experiments, with the assistance of Mr. S. PIERCE, I combined lenses of such proportions, that they admitted of being separated from each other so as to Magnify at one extremity, *more* than double what they did at the other, the vision continuing uniformly distinct.

"Having now done more than had been previously effected, I brought it to You. The approbation You expressed of what I had done, so encouraged me, that I applied unceasingly, determined to perfect the object in view, which I have now accomplished.

"I beg to present to you the following accurate measurement of the powers, and faithful account of the performance of

"The PANCRATIC EYE-TUBE, which I think gives a better defined image of a fixed Star,—and shews Double Stars decidedly more distinct*, and perfectly separated, than any other Eye-tube, and I hope will enable us to determine the distances of

* Especially in Achromatic Telescopes, which are, what is termed, a little *over-corrected,* and the purple rays predominate: that is, when the focal length of the *Convex Lens,* is formed rather too long for the *Concave.*

these objects from each other, in a more perfect manner than has been possible heretofore*.

"This Eye-tube, when accurately made, applied to an Achromatic of 44 inches focus, produces, in the most perfect manner, every intermediate degree of Magnifying power between 100 and 400, either for Celestial or Terrestrial uses — the *Field*† *of Vision continuing uniformly distinct.*

* This is accounted for, from the greater degree of the aberration arising from the extreme sphericity of the lenses in Eye-pieces composed of One or Two lenses which magnify so highly. "If any one, for instance, would have the visual angle of a Telescope to contain 20 degrees, the extreme pencils of the field must be bent or refracted in an angle of 10 degrees; which, if it be performed by *One* Eye-glass, will cause an aberration from the figure, in proportion to the cube of that angle: but if *Two* Eye-glasses are so proportioned and situated, as that the refraction may be equally divided between them, they will each of them produce a refraction equal to half the required angle: and therefore the aberration being in proportion to the cube of half the angle taken twice over, will be but a fourth part of that which is in proportion to the cube of the whole angle; because twice the cube of *One* is but ¼th of the cube of *Two*; so the aberration from the figure, where *Two* Eye-glasses are rightly proportioned, is but ¼th of what it must unavoidably be where the whole is performed by *a Single Eye-glass.*—See Mr. J. Dollond's Letter to Mr. Short, *Phil. Trans.* for 1753—and see a luminous paper on *the Aberrations of Compound Lenses and Object-Glasses, by* J. F. W. Herschel, Esq., F.R.S. in the *Phil. Trans. for* 1821.—See a proof that the Theory of this profound Mathematician is practically true, in Chapter XX. of this work.

† It may be said that common Eye-tubes have rather a large

"Therefore it is presumed, that the advantage of my PANCRATIC Eye-tube over the usual common Eye-tube, in variety of Magnifying power,—convenience,—cheapness,—and portability,—is as 300 to 1.—The cost of a common Eye-tube is One Pound; of the Pancratic only Two Pounds, Two Shillings.

"*The Tubes are graduated;* every 10 degrees, thus, 100, 110, 120, up to 400.

"The change from one Power to another may be made instantaneously, with the utmost facility and certainty, and the Observer always knows exactly what power he is using."

[The above is an extract from Dr. Kitchiner's Letter to Sir JOSEPH BANKS, P.R.S., which was read at the meeting of the R.S. on the 20th of April, 1820.]

Another is made, which is adapted for TERRESTRIAL purposes, Magnifying with an Achromatic of 44 inches focus, from 55 to 200 times—and with a 30 inch from 40 to 160.

*The power it will give to a Telescope,* is according to the focal length thereof, and is easily found by the

field—but of what use is that part of the field in which objects appear distorted and fringed with Colour?

That, can only be considered the actual and useful field of view, the Margin of which, is as perfectly distinct as the middle of the field, when the Telescope is adjusted at an object seen in the middle of the field.

Rule of Three; for instance—if the Telescope be of 18 inches focus—

If a Telescope of 44 Inches gives } 55 { what will one of 18 Inches?

$$\begin{array}{r} 18 \\ \hline 440 \\ 55 \\ \hline 44)990(22\tfrac{1}{2} \\ 88 \\ \hline 110 \\ 88 \\ \hline 22 \end{array}$$

$22\frac{1}{2}$ the Magnifying Power with an 18 Inch.

from $22\frac{1}{2}$ times, up to 88—being as low a power as is requisite for *Land Objects*—and as high as is requisite to shew *the Ring of Saturn,—the Belts and Satellites of Jupiter* and several *Double Stars.*

If the Pancratic be applied to a Telescope with sliding tubes, it is desirable, on account of the great power it produces, that it should have a Stand and an *Adjusting Screw* with a tooth and pinion; these are made separate from the Telescope, and introduced between the first and second sliding tubes—Mr. Price, *of Fetter Lane, Fleet Street,* made such a one for me.—See p. 197, and the foot of p. 33.

*The Advantage—of having* ALL *Powers in* ONE *Eye-tube* is sufficiently obvious.

In some *Clear* Days the Air is so transparent, that

we can use a power of 100 for Land Objects, and on objects well illuminated sometimes 150, as well as in some other days we can a power of 50.— *See the second paragraph in* p. 193.

Telescopes act best when used in the same direction that the Sun shines.—I have known good Telescopes condemned by trying them upon objects situated towards the East in the morning, or the West in the evening.

*To have Perfect Vision*—every Day, and every Object, must have its appropriate degree of Magnifying* power!—this can only be accomplished by the *Pancratic Eye-tube.*

On the 25th of March, 1819, Mr. Pierce, the Optician, with a Pancratic Eye-tube which made a 1 foot Achromatic magnify 80 times, perceived *α Geminorum* to be double

On the 5th of April, 1819, I shewed this with a power of 80 to Mr. Wm. Brockedon, the Painter, and to Mr. Charles Turner, the Mezzotinto Engraver in Ordinary to His Majesty.

*α Geminorum* requires very little *Illuminating* Power; I have shewn it to several persons who did not know that it was a Double star, with two 1 foot

* "The effective Power of Telescopes has a considerable range of extent,—and can only be assigned—when the object to be viewed is given."—Sir Wm. Herschel, in vol. cv. of the *Phil. Trans.* p. 294., and the abstract therefrom, at the end of Chapter XVII. of this work.

portable Telescopes, with an Object-glass of the usual aperture of $1\frac{1}{10}$th inch in diameter, to which I applied a *Pancratic* Eye-tube, which gave a power of 80 times, and they described to me its appearance very accurately.

I have seen these two Stars with 230 in my Achromatic Telescope of 28 inches focus, and $2\frac{3}{4}$ths inches aperture, (which was made by the present Mr. Dollond for the late Mr. G. Hodgson, at whose sale, in February 1824, I purchased it,) like Two Shillings on a bit of Black Cloth—and as distinctly, though not so widely separated as in Sir Wm. HERSCHEL's Diagram of *Castor*, as it appeared in his 7 feet Newtonian with 460.—See the *Phil. Trans.* for 1782, and the *Frontispiece* to this work.

ε *Bootis*, was observed on the 25th of May, 1819, by Mr. H. Browne, F.R.S. and myself, with an Achromatic Telescope of $2\frac{7}{10}$ths aperture, made by Mr. George Dolland, F.R.S. With a Pancratic Eye-tube magnifying 270 the two Stars were perfectly and distinctly defined, without either rings or rays, &c. around them. This was in a fine clear evening—the air quite still—and the star very near the meridian. The *Blue* colour of the smaller star was remarkably bright for so small an aperture.—This Double Star is *very rarely* seen quite distinctly, in an Achromatic with a less aperture than $3\frac{1}{4}$, or in a Gregorian Reflector of less than 5 inches, and a Power of at least 270.

*Sir William Herschel* saw it in his 7 feet Newtonian when its aperture was limited to 3½ inches; "with 460 the vacancy between the Stars was ⅛ a diameter of the smallest."—See *Phil. Trans.* vol. xcv. p. 42.

Well might *Dr. Maskelyne* say, that "Telescopes of *Sir Isaac Newton's* construction perform most excellently in the *Minutiæ* of Astronomy, especially if small Apertures and long Foci are made use of."—See *Supplement to the Nautical Almanack for* 1787, p. 42.

N.B. The Reader is cautioned, that my *Pancratic Eye-tube*, is composed of *Three Inner, and an Outer Tube*, and that when all drawn out, it is 14 inches and ⅜ths in length;—when shut up, not more than 5½ inches;—and that when drawn out, the magnifying power is Quadruple what it is when the tubes are shut up.

As I have no Interest in the sale of this Eye-tube, I have considered myself at liberty to state my opinion freely upon it—it is made by Mr. Dollond, and sold at £2. 2*s*.—for £1. 1*s*. more than the common Eye-tubes.

On the old Plan, *Two* Magnifying powers cost £2. 2*s*.: with the Pancratic, you have *Three Hundred* for £2. 2*s*.

*None are Genuine but those precisely answering the above description*, and which exactly resemble the engraving opposite page 130, and have the following inscription engraven on the Outer Tube:—

"The PANCRATIC Eye-tube: Invented by WM. KITCHINER, M.D."

This remark is necessary, because certain persons have found it convenient to construct *Counterfeits** made *with only* ONE *Tube* — which have not half the variety of powers *the Pancratic* has, and consequently, magnify not *Half* so low—nor *Half* so high as they ought.

* To construct this Eye-tube perfectly, requires All care and excellent workmanship—the Lenses must be All of exactly the right focus—All without any blemish—and the Glasses and the Tubes containing them must be very truly centred with regard to each other, and to the Object-Glass.

## CHAPTER XIV.

### MAGNIFYING POWERS FOR ASTRONOMY.

You should not have less than Nine Eye-tubes for Celestial purposes, or your Economy will be as unwise as that of the Cook who "spoilt the Broth for want of a Halfpennyworth of Salt"—each Eye must have the Telescope adjusted to its own peculiar focus, — Each Object must have its own peculiar magnifying power.

These Eye-tubes cost about £1. 1*s*. each.

15 for Comets.
45 for the Sun, or Moon, Nebula, &c.
60 for Ditto.
80 for Jupiter and his Moons.
130 for Jupiter and Saturn.
160 for Ditto.
200 for Ditto, and Double Stars.
300 for Double Stars.
400 for Ditto.

For more particular directions for the application of these Eye-pieces, see p. 47 of Chapter IV. on *a* 3½ *and a* 5 *feet Achromatic* — and page 140 of Chapter VIII. on a 7 *feet Newtonian*—and the following Chapter.

When two or more Glasses are fixed into a tube,

at certain distances from each other, they are called *An Eye-piece;* and whether intended for erect or inverted vision, they are in fact compound Microscopes, whereby the image of an object, formed in the focus of the Object-Glass, is seen and magnified.

The Glasses must be perfectly well polished, and as thin as possible for their curvature; which, together with their distance from each other, must be so proportioned, that the visual angle, or field of view of the Telescope, be as large as possible, and uniformly distinct to the very edge of it: and it is absolutely necessary in the setting of them, that the centre of the Glasses be placed exactly in the axis of the Tube, and the surface of them fitted into the cells exactly parallel to each other.

The *Astronomical Eye-pieces* for Achromatic and Newtonian Telescopes, are usually of the Huygenian construction, and are composed of two *plano-convex* Glasses, whose plane sides are next to the Eye, and whose foci are as 1 to 3. If a plano-convex lens of *one* inch focus, be placed at two inches distance from one of *three* inches focus, their magnifying power will be equal to a single lens of one inch and a half focus:—the lens next to the Eye is called *the Eye-glass;* that next to the Object is termed *the Field-glass.*

The spherical and colorific aberrations are said to be better corrected by this combination; and it has

a larger and more uniformly distinct field of view than any other Eye-tube composed of two Glasses.—See the end of Chapter V. on *Single Concaves and Convexes.*

If the two Lenses which compose an Huygenian Eye-piece, are of proper proportions—if you take away the 1st glass next to the Eye—the 2d glass alone will magnify only about half as much as the Two do when used together:—if you take away the 2d glass, and use the Glass next to the Eye by itself, it will magnify about ⅓d more than the two lenses do when used together—thus supposing them together to magnify 100 times—the 2d glass used alone will magnify 50—and the 1st glass used alone will magnify 150:—thus in each Huygenian Eye-tube, you have in fact three Magnifying Powers.—See the account of the *Eye-pieces* to the 5 *feet Achromatic*, in p. 47 of Chapter IV.

1st. I recommend that each Eye-tube be attached to a lengthening piece, which, when fixed to the Telescope, will, when it is adjusted to one power, be very nearly adjusted to all—this will be found a great convenience, especially in applying extremely High and extremely Low powers, and save a great deal of work to the observer, and a great deal of wear to the Adjusting screw.

2d. It is much more convenient to have Eye-pieces made to *slide* into the Tube, than to *screw*

in—they are more readily changed, especially in cold dark nights when our fingers are benumbed with cold.

3d. *The Caps of Eye-pieces,* instead of screwing on, should slip on like the covers of Object-Glasses, and *the Dark Glass* of the Comet and Moon Eye-tube, should be of a very light Green colour—which will be found extremely useful in observing the planet Venus.

4th. *The Second,* or Field glass, requires a cap quite as much as *the First* or Eye-glass does—indeed the 2d is generally much more exposed than the 1st glass is—both ought to be shielded from dust and air, and kept as clean as possible—for as often as they are wiped, they are in danger of being scratched, &c.

5th. *The Cells* containing the Eye-glasses should be so contrived, that the glasses may be perfectly comeatable to be cleaned, especially the high powers, which I have seen set in such a deep cell, that it was impossible to wipe them properly—but the *Rim* of the cell of Eye-Glasses and of Object-Glasses should project so far beyond them, that they may be laid down without their surfaces touching any thing.

6th. *The Eye-glasses* should be so carefully proportioned to each other, and so placed that the Eye may view *the whole of the field at once,* without the Eye touching the Tube or moving before it. "The

hole through which the Optic Pencil passes in coming to the Eye should be much larger than the diameter of the pencil, and considerably nearer the Glass than their focus; for the Eye ought on no account to come in contact with the Eye-piece—nor should it be touched by the hand."—Sir WILLIAM HERSCHEL, in *Phil. Trans.* vol. cv. p. 295.

Read the *Obs.* on the *Eye-head* of *Eye-pieces*, in p. 198 of the Chapter on the *Magnifying Power of Day Telescopes.*

7th. The Magnifying power given by *Ramsden's Dynameter* should be engraved on each Eye-tube.

LASTLY. Have all your Eye-tubes packed in a box, which may be packed itself in the case in which the Telescope, &c. is packed:—the usual way of packing them in the same box with the Telescope is extremely inconvenient—that case is a great cumbersome thing, which is generally put out of the way; and the Eye-tubes are left about exposed to dust, &c. If they are put into a small box, as recommended above, they can always stand by the Telescope, ready for action, and be securely defended from dust, &c.

When the Inventors of the Achromatic Telescopes fixed the Magnifying powers of those Instruments, it is presumed that they did not do so till after due deliberation, and a conviction resulting from actual experiment, that for *Planetary* uses, the highest

proportion of the diameter of the Object-Glass to the Pencil of Rays, was as 1 to 40. Thus the 30 inch Achromatic, which has an aperture of 2 inches, magnifies 80 times; and the 5 feet Achromatic, which has an aperture of nearly 4 inches, generally shews *Saturn* best, with a power of about 160, (see Chapter on *Saturn*,) to bear a higher power; the air must be very clear, and the planet very near to the Meridian; and the defining power of the Telescope exquisitely perfect.

When the Pencil of Rays is too diluted to perfectly excite the action of the Eye, we lose in distinctness by the Magnifying power being in too high a ratio to the Illuminating power. "An object appears brighter, or fainter, according to the Magnifying power—for the same quantity of light being spread over a greater or smaller surface, renders the image obscurer or brighter."

As Sound, when diminished beyond a certain degree, becomes too faint to excite a sufficient vibration of the tympanum, to convey tones distinctly, and at length they become inaudible; in like manner, when the pencil of Light is less in diameter than $\frac{1}{50}$th of an inch, unless it be from a star of intense brightness, its stimulus to the Optic nerve becomes too languid to excite its perfect action.

We must always take into our account, not only the *Bigness* but the *Brightness* of the pencil of rays, which is as the Brightness, and the degree of the

Illumination of the Object; and the construction of, and the defining power of the Telescope.—(See Chapter XVII. on *Illuminating Power.*)

From the rapidity of the Rotatory motion of the Earth—the limited Excitability of the Eye—and the irremediable Impediments to vision from our magnifying the Atmospheric medium which we look through, in proportion as we magnify the objects which we look at, increasing in so high a ratio to the Magnifying power:—

More than 100 for Terrestrial,

More than double that, or 200 for Planets,

and more than double that, or 400 for Double Stars; nine days and nights out of ten impedes, rather than assists Vision.

When we charge our Telescopes with a higher power than 400, even with the steadiest Stand, and the best contrived Rackwork, &c., very uncommon dexterity is required both to find the object, and to manage the Instrument—and a higher Magnifier will very rarely be used to any advantage—*till the Atmosphere be removed, and the Earth stands still.*

I must here except some half a dozen minute Double Stars—which nobody can wish to see for any other reason, than merely because it is difficult to see them:—those Double Stars are the best adapted for every useful purpose, which are easily visible, and are distinctly defined with instruments of moderate size.—Gentle Reader, I earnestly invoke

your Common sense, to maintain your Author in this position, in defiance of all the wrathful anathemas which you may have whispered to you by those crabbed Philosophers, who love to make people think that nothing is desirable but what is difficult; and that to be incomprehensible is the true sublime.

Beyond a certain boundary, *Illuminating* Power is as useless as *Magnifying* Power; and both are totally inefficient without a due proportion of *Defining* Power; and the failure of the latter in Achromatic Telescopes beyond $3\frac{8}{10}$ths in diameter, and in Reflectors beyond 7 inches, is the cause why those who purchase larger Telescopes are generally disappointed, in the advantage which they expect from the increased aperture.

A certain quantity of light is needful, more is inconvenient; the degree of Light that is useful, is limited by the nature of our Eye—as the degree of *Magnifying power* is by the nature of the atmosphere; which, for observing Planets, will not bear more than 250, no matter how large the Telescope.—See Chapter XVII.

Mr. Tulley informed me, that with the *Cassegranian* Reflector, which he finished in the year 1802, and which had an Aperture of 15 inches—that Planets were best seen with a power of 200, or 250 at the utmost; he shewed *Saturn* to me, with those Powers, beyond which it was not so well defined:—I have not, and Mr. Tulley, and several Prac-

tical Opticians, have informed me, that they have not seen any Telescope that would, with any advantage, bear a higher power for observing Planets; and the superiority of Reflectors beyond 7 inches in diameter, is not so great as might be expected, only that they shew a greater number of small Stars; but as the Poet says—

> "Stars above a certain height,
> Give mortals neither heat nor light."

See Sir W. H.'s *Obs.* on his 20 *feet Reflector,* which had an Aperture of 18⅔ inches, in *Index.*

The Telescope must be furnished with

A FINDER,

which is a very Small Telescope that is fixed on the Large one, and magnifies only about 5 or 7 times; and having a very extensive field, an object is easily found with it:—at the focus of the Eye-tube of this Finder there are placed two *Wires,* which cross each other in the axis of the Telescope,—which Wires are often too fine—they *should be thick enough to be easily seen at night:*—this Finder is so adjusted, that when any object seen in it, is at the crossing of the lines, it is at the same time in the centre of the Large Telescope.

By the assistance of the Finder much time is saved in finding objects, especially when great powers are used; and it saves the Eye a great deal

of very irksome labour, which is extremely distressing and injurious to it.

### SIR WM. HERSCHEL'S FINDER.

"The finder of my Reflector is limited, by a proper diaphragm, to a natural field of 2° of a great circle in diameter. The intersection of the cross wires in the centre of it, points out 1°; and by the Eye this degree, or the distance from the centre to the circumference, may be divided into $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, $\frac{1}{3}$, and $\frac{2}{3}$ds.—See Sir W. H.'s 2d Catalogue of Double Stars, in the *Phil. Trans. for* 1785.

My favourite Finder is a 1 foot Achromatic, with an Eye-tube composed of two Glasses, which magnify about 6 times, — it is easily and accurately adjustable by two finger screws acting against a spring; and was made for me by Mr. DOLLOND.

*The Finder for a Gregorian Reflector*—must be a 1 foot Achromatic, with an erect Eye-tube magnifying 10 times—this will be useful for Terrestrial as well as for Celestial purposes—as the vision is erect in the Telescope, it ought to be so in the Finder.

If the Finder is not exactly centred to the Telescope — as soon as you find the object with the Telescope, look in what part of the field of the Finder it is.

Persons unaccustomed to point a Telescope at a Celestial object, with a higher power than 60, will

be puzzled how to direct it, and in trying to do so, and staring in vain at vacant space, will sadly strain their sight.

To all Telescopes magnifying more, A FINDER is an indispensable assistant to the most expert observer—so is an ADJUSTING SCREW to regulate the focus.

*No Sliding Telescopes should be more than* 30 *Inches in length:* if they are, the portable stands are not steady enough for Astronomical purposes—and also the Finder and Adjusting Screw are wanted.—See p. 33.

LASTLY. It is very important that the *Cross wires* be placed at such a distance from the Eye-piece of the Finder—that when that is adjusted for shewing Jupiter, &c. sharply defined, that the wires in the Finder may be sharply defined also. The place of the wires, therefore, must be adapted to the peculiar focus of the Eye of the person who is to observe with them, the adjustment required for a long old Eye, is useless to a young one, especially to one that is at all short-sighted.

A Power of 20 or 30, with cross wires in it, is a good substitute for a fixed Finder.

*To point a Telescope at an object,* do not lay hold of the Eye-piece, or Tail-piece, but of the main Tube of the Telescope.

The Telescope should be suspended in the centre

of gravity,—and mounted on a portable folding mahogany stand, with divided circles, and a universal Polar adjustment.

If the instrument be then placed in the plane of the Equator, one motion only will be required to follow the object; which, when great Magnifiers are used, is a very great advantage, as the tremours occasioned by the movements of the Rackwork are diminished in like proportion.

*The Stand must be high enough* to admit of the observer being comfortably seated under the Eye-tube, when the Telescope is elevated to 75 degrees: this in a 5 feet Achromatic will be about 3 inches higher than the person can put his Eye to, when the instrument is placed in an horizontal position.

THE COMET EYE-PIECE

should be constructed with a very large and uniformly distinct field, and should not magnify more than 12 or 15 times.

The glasses in this Eye-tube should not be less than Two Inches in diameter—indeed, it would be extremely desirable if the Aperture at the Eye-end of Astronomical Telescopes was large enough to receive the Eye-tube usually put to the large Inverting Night-glasses.

During the appearance of the Comet, in August 1811, *a Vulgar Error* prevailed, that a common Opera-glass would afford the eye more assistance

than a Telescope.—This must have arisen from Telescopes not being usually furnished with a sufficient variety of Eye-pieces;—for, although *Comets* are commonly enveloped in a veil of dense atmosphere, which partly prevents the operations of *Magnifying* power,—the *Illuminating* power of a large glass may be employed with great advantage: and with a proper *Comet Eye-piece*, the larger the Telescope, the more distinctly we shall discern the *Nucleus* and its appendages.

I have an Eye-piece of this kind, that exhibited the Comet of September 1811, very satisfactorily, the field of view being sufficiently large to shew the Comet, and its paraphernalia of light which accompanied it: and as it is a delightful Eye-piece for viewing *Nebula* and the *Milky Way*, &c. it will be found a very useful addition to the apparatus of the Telescope, and will serve for all the purposes of a Night-glass.

In the *Phil. Trans. for* 1787, and page 55 of vol. lxxvii. that honest and accurate Practical Astronomer, to whom we are indebted for so many important observations and improvements in instruments, the Rev. F. WOLLASTON, recommends, for observing COMETS, " a Telescope with an Achromatic Object-glass of DOLLOND, of 16 inches focal length, and 2 inches aperture; with a Ramsden's Eye-glass, magnifying about 25 times, mounted on a very firm equatorial stand, the field of view taking

in 2 degrees of a great circle," and furnished with a set of Mr. W.'s system of wires, described in vol. lxxv. of *Phil. Trans.* p. 346, he says,

"Upon the whole, I think I may with confidence recommend such an instrument for sweeping the Heavens, and pretty well ascertaining the position of what one discovers; and with it, I can observe stars down to what I call the tenth or eleventh magnitude, and, I think, with some degree of precision."

### FOR OBSERVING ECLIPSES OF THE SUN OR MOON,

a power of about 30 times will be found most useful, as it will shew the whole of their face, and leave plenty of margin around them.

Should any of our readers not be provided with a coloured or *Smoked Glass* at the time an eclipse takes place, they may observe the image of the sun in a bucket of water, placed in a situation where the surface is not agitated by the wind. But it will be much better to be provided with a proper glass for this purpose; and one of the best that can be used is so easily prepared, and so effectual when properly done, that we shall insert the late Dr. Maskelyne's method of smoking glasses for this purpose. He observes, "Dark glasses should be used to defend the eye from the intensity of the sun's light. Transparent glasses, smoked over the flame of a candle or lamp, will give a more distinct and

agreeable vision of the disk of the sun, than any tinged or coloured glasses will do. Provide two pieces of glass of a convenient length, not too thick (the common crown glass used for windows will do as well as any), wipe them clean and dry, warm them a little by the fire (if the weather be cold), to prevent their cracking when applied to the flame of the candle; then draw one of them gently, according to its whole length, through the flame, and part of the smoke will adhere to the glass. Repeat the same operation, only leaving a little part at the end untouched, and so each time leave a further part of the same end untouched, till at last you have tinged the glass with several dyes, increasing gradually in blackness from one end of the glass to the other. Smoke the other glass in like manner; and apply the two glasses one against the other, only separated by a rectangular border, cut of glass, or card paper, the smoked faces being opposed to each other, and the deepest tinges of both placed together at the same end. Tie the glasses firmly together with waxen thread, and they are ready for use. The tinge at one end should be the slightest possible, and at the other end so dark that you cannot see the candle through. By this contrivance, applied between your eye and the sun, you will have the advantage not only of seeing the sun's light white, according to its natural colour, and his image more distinct than through common dark glasses, but also

of being able to intercept more or less of his light as you please, and, as the clearness or thickness of the air requires it, by bringing a darker or lighter part of this combined dark glass before your eye; which will be a great convenience at all times, but particularly when the brightness of the sun is liable to sudden changes from flying clouds."

Mr. WOLLASTON mentions, observing the Eclipse of the Moon, on Sept. 10, 1783—" With my 46 Inch Achromatic, the aperture reduced to 2 inches, with a small magnifying power of 36 times, which I had made by Mr. Dollond, for those observations, and I found very convenient."—See *Phil. Trans. for* 1784, vol. lxxiv. p. 194.

The Grand Dandy Opera-Glass which magnifies Twice, is an excellent Instrument to assist the Sight of *Short-sighted* persons, who will find it a convenient assistant to find a Planet early in the evening, and to give them *a General View of the Constellations,*—and it also deserves to be recommended as an excellent Finder to such as are fond of turning out on a fine frosty night to sweep the sky for a *Comet*. — Dr. MASKELYNE, who was short-sighted, had for this purpose a *Binocular Opera-Glass,* i. e. two Opera-Glasses, magnifying about twice, fixed in the opening of a Spectacle frame, which he placed before his Eyes, like as you put on Spectacles. I remember seeing a pair of such Spectacles in the Observatories, of Mr.

LARKINS, on Blackheath Point; of Mr. AUBERT, at Highbury; and of Mr. HODGSON, at Hoddesdon.

A large NIGHT-GLASS will be found a very useful Instrument in the observatory, for obtaining a more intimate acquaintance with the Constellations, and for doing the business of *a Sweeper*. By using *a Prism Eye-piece*, it may be slung in as convenient a manner as a Newtonian reflector, and the Eye of the observer remain at rest while the Telescope moves from the Horizon to the Zenith: it is also well adapted for observing Comets.

FOR OBSERVING THE FULL MOON,

the lowest Day-piece will do very well, if it does not magnify more than 45 times; and if it is properly constructed, it will shew *the whole of the Moon* with a margin round it.

But I would advise an Huygenian Eye-tube of 45, as it is short and convenient, and serves for other purposes—the Sun—Nebula—the Milky Way, &c.

A long and large Achromatic or a Newtonian, is the best instrument for viewing the whole of the Moon — Gregorian Telescopes have seldom a sufficiently low power, and large field for this purpose.

*For examining particular parts of the Moon*—the advantage of light or Illuminating power appears to be as great, if not greater than it is upon any other object: — I first observed this, when comparing my

3 feet Gregorian, which has an aperture of $9\frac{3}{10}$ths inches, with my 7 feet Herschel Newtonian, which has $6\frac{3}{10}$ths inches aperture. Many parts of the Moon became plainly visible, with the Speculum of $9\frac{3}{10}$ths inches — which were not visible in that of $6\frac{3}{10}$ths — and were not visible in the $9\frac{3}{10}$ths when contracted to 6 inches. — The magnifying power employed was only 90 times, and the same in each Telescope.

Jupiter, the same evening, appeared in this Gregorian quite as bright with 180 as it did with 90.

FOR OBSERVING PLANETS,

in the list of Magnifying Powers, I have set down 80, 130, 160, 200.

There is *a Vulgar Error* almost universally prevalent, that SATURN (see Chapter on *Saturn*) will bear a higher magnifying power than JUPITER, notwithstanding *Jove's* complexion is much brighter than *Saturn's*. My own experience has told me, what common sense will teach any thinking mind, that *Jupiter* will bear a high power better than *Saturn*, in proportion as he shines with more vivid light*.

* Though many Optical writers have offered many observations on the requisite Diameter, &c. of the pencil of Rays, none seem to have considered the Quality of them.

A pencil of Rays, of *intrinsic Light*, of the 60th of an inch diameter, proceeding from an intensely bright object, *i. e.* a fixed

The reason why this *Vulgar Error* is so universal, I fancy, must be because *Jupiter* is so bright an object, especially when near to the Meridian, that only a very perfect glass will shew it well.

This is a fact which I have myself ascertained: it always appeared an unaccountable paradox to me, that an *obscure* object would bear a greater power than a *bright* one; which was the positive assertion of almost all the Opticians and Astronomers, &c. I have conversed with on the subject.

I recommend my Reader to be exceedingly cautious in crediting any assertions which are contrary to Common Sense, which I consult in Occult questions, as well as in Ordinary ones; and, since miracles are no more, and Oracles (excepting, I hope you will say, courteous Reader, "THE COOK'S ORACLE,") are obsolete, is the standard, by which all marvellous and unaccountable stories should be scrupulously measured, before Rational beings suffer themselves to be so paralysed by Indolence as to let them pass current for facts.

The Phenomena on the Face of *Jupiter* may be

Star, will stimulate the Optic nerve as much as a pencil of *reflected Light* of the 20th of an inch diameter,—*i. e.* from Jupiter or Saturn, as those Planets require from an Achromatic Telescope a pencil of Rays which is not less than a 30th of an inch in diameter—so a fixed Star hardly begins to shew a decidedly defined disk, like a Planet, till the pencil is less than the 60th of an inch in diameter.—See Chapter XX. on *Double Stars.*—W. K.

seen very pleasantly with powers of from 130 to 250, but those of *Saturn* only just begin to be visible with 130—and to see them perfectly well you must have a magnifying power of about 200 times, and an Object-Glass of 4, or a Speculum of 7 Inches in diameter.

All Telescopes should have an Astronomical Eye-tube magnifying 80 times, because it has a field of view large enough to shew *Jupiter* with all his Moons, and a margin of sky round them; and it is, therefore, a convenient power to shew them with to others.

One of the laws which governs the application of Magnifying Power, is that it may be applied in proportion to the brightness of the object that we are observing—to some of the Fixed Stars of the first magnitude there appears to be no limit to it, except the Atmosphere.—See *Obs.* on *α Lyræ,* in page 235.

FOR OBSERVING STARS,

I have recommended an *Huygenian* Eye-tube, magnifying 400 times, as the greatest power that is usually needful, as it is difficult to find the object with this High power, and it passes through the field very rapidly, I would not have it limited by a stop, which is very properly introduced to cut off the aberration in Low powers, for the indistinct margin is useful in catching and keeping an Object.—

See page 200 on the *Pancratic,* which magnifies from 100 to 400; and, if required, with the same ease and expense, may be made to magnify from 200 to 800.

*A Circle of Six Convex Lenses,* set in a Wheel, is a convenient Eye-piece for ascertaining the effect of different degrees of Magnifying power; but they must be very carefully centred, — the importance of exact centering increases in the proportion that their magnifying power increases :—they must also be set so that each is easily comeatable to be cleaned, a Camel's-hair brush is, perhaps, the best thing to remove dust from them; — they should be defended from dust and air as much as possible, and therefore are best kept in a close box.

As often as a Glass is wiped, however carefully it is done with the smoothest and cleanest Lamb's-skin leather, still it is as often in danger of being scratched.

A Wheel of Two inches in diameter, will contain 6 Lenses and a blank to fill the Aperture, so that the Glasses may always be kept covered : it will be convenient that the 1st Lens be a very low power, that it may serve as a Finder for the others, and the Wheel should be made to turn both ways.

*A Convex Lens of One Inch focus* will make an Achromatic or a Newtonian Telescope magnify as many times as its Object-Glass or Object-Speculum is of inches in focal length: *i. e.* it will make a

30 Inch Achromatic, with an Eye-glass of 1 inch focus, magnify 30 times.

The 2d Lens may be of half an Inch focus—and the Magnifying power given by that is ascertained by multiplying the focal length of the Telescope by 2—i. e. *a Convex Lens of half an inch focus* will give an Achromatic or Newtonian Telescope of 30 inches focus, a Magnifying power of 60 times.

I would recommend the 3d Lens to be of the $\frac{1}{3}$d of an inch focus.

The 4th of the $\frac{1}{4}$th of ditto.

The 5th of the $\frac{1}{6}$th of ditto.

The 6th of the $\frac{1}{10}$th of ditto.

| Lens. | Focal Length of Eye-Glass. | Magnifying Power, with 30 Inch Achromatic. | Magnifying Power, with 3½ feet or 44 Inch Achromatic. | Magnifying Power, with 5 feet or 63 Inch Achromatic. | Magnifying Power, with a 7feet or 84Inch Newtonian. |
|---|---|---|---|---|---|
| No. | Inches. | | | | |
| 1 | 1 | 30 | 44 | 63 | 84 |
| 2 | | 60 | 88 | 126 | 168 |
| 3 | $\frac{1}{3}$ | 90 | 132 | 189 | 252 |
| 4 | $\frac{1}{4}$ | 120 | 1[illegible]5 | 252 | 336 |
| 5 | $\frac{1}{6}$ | 180 | 264 | 378 | 504 |
| 6 | $\frac{1}{10}$ | 300 | 440 | 630 | 840 |

The foregoing Table clearly demonstrates one of the causes of the diminution of the aberration in Long Telescopes—to obtain a power of 300, in a Telescope of 30 inches focus, requires a lens of only $\frac{1}{10}$th of an inch focus—in a Telescope of 84 inches

focus, a power of 336 is obtained with a lens of ¼th of an inch focus.

A Lens of $\frac{1}{10}$th of an inch focus is as deep as can be applied to any Telescope with any advantage—however perfect the Instrument, and however bright the object.

No Achromatic or Newtonian Telescope will bear distinctly a higher power than that given by multiplying the focal length in inches of its Object-Glass or metal by 10—for instance, if you use a lens the $\frac{1}{15}$th of an inch focus to a 3½ feet Achromatic Telescope of $2\frac{7}{10}$ths inches aperture, and 44 inches focus, you will find in the brightest day that the object will appear as if there was a thin veil of Black Crape placed between it and the Telescope, or as if a fine Cobweb was before it; and if turned to Celestial objects, the Belts of Jupiter are hardly discernible, and Stars appear in a kind of *halo*, and the *Defining* power of the Instrument is quite destroyed.—See the Introductory Chapter on *Double Stars*.

" Those who are least experienced are most desirous of *deep Magnifiers*, and extremely inquisitive about lenses of the shortest focal distances; and they suppose it may be known when they are $\frac{1}{10}$th. $\frac{1}{20}$th, $\frac{1}{30}$th, $\frac{1}{40}$th, or $\frac{1}{50}$th of an inch, as well as when they have focal distances of 1, 2, 3, 4, or 5 inches; but herein they are strangely mistaken, for it would puzzle a NEWTON himself, to determine precisely

what is the *Solar focal Distance* of one of those very small Lenses. Nor would it boot any of these over-curious Geniuses, to be informed what the focal Distance of a very small Lens or Spherule really is; for they could not from thence conclude any thing in regard to the Magnifying Power, or Dimension of small Objects, as they seem to expect. Nor can it answer any other Purpose than pure Curiosity, that I know of."—BEN MARTIN *on Micrometers*, 8vo, p. 3.—See more on this subject in Chapter XVI.

## CHAPTER XV.

### DIAGONAL EYE-TUBES.

WHEN we wish to discern those delicate and minute objects, which are the most interesting exhibitions our Telescopes display to us, and with the finest Instruments are only discernible with the most favourable circumstances,—we must be in a position of the greatest ease: no cramp or painful posture must distort the Body, or irritate the Mind;—the whole powers of which must be concentrated in the Eye.

Such is the sympathy between the various Organs of the human body, that we may as well attempt to think accurately on two Subjects at the same time, as to use two Senses at the same moment:—each must be used alone, if we wish to give it a fair chance of doing its utmost.—As *Shakspeare* has observed of Listening with such profound attention, that " each other Sense was lost in that of Hearing."

To avoid the painful position when observing Celestial objects when they are near the Zenith, I have tried 8 different kinds of Diagonal Eye-tubes. Several of them are so constructed that they will apply to, or will receive all the Eye-pieces, and render an

*Achromatic* Refracting Telescope, or a *Gregorian* as convenient as a *Newtonian* Reflector.

The diminution of light by the Diagonal is scarcely perceptible when observing the Moon or the fixed stars—such is the intense intrinsic brightness of the *Fixed Stars*, that the inferior degree of vividness of the pencil of rays is, I may say, imperceptible.

" *α Lyræ*, I surmise, has Light enough to bear being magnified at least a hundred thousand times, with no more than 6 inches of aperture, provided we could have such a power, and other considerations would allow us to apply it."—See Sir Wm. Herschel's First Catalogue of Double Stars, in the *Phil. Trans.* for 1782.

The position is not only pleasanter, but the organ of sight is more perfect, when we look comfortably straight forwards—than it is when the head is bent back in the break-neck position required in observing objects in a high Altitude without such assistance.

It may be urged, that a *Prism* would bend up the rays with less loss of brightness than a *Speculum* can reflect them—but in the latter you have only *One* surface to get worked truly, and it is no easy thing to obtain that quite good*—in the former

* "I find more difficulty in correcting the figure of the little *plain* piece of metal next the Eye-glass than one would expect."—See Sir Isaac Newton's Letter in the *Phil. Trans.* for 1672, vol. vii. p. 4032; and Sir William Herschel's Obs. in Oct. 12,

*Three*, and the imperfections of the Glass to contend with into the bargain :—the facilities of construction are thus at least three to one in favour of Specula : but if *the Bull's Eye Prism* be perfectly good, that is incomparably the best Diagonal Eye-piece — that it can be made good, I know, because I have one which is as sharp, though not so bright, as a Single Lens.

1st. A Plane Speculum placed at an angle of 45 degrees between the Object-glass and the Eye-glasses.

2d. A Plane Speculum, fixed at the like angle, is placed next to the Eye, before the Eye-tube.

3d. A Plane Speculum is placed between the Eye-glass next to the Eye, and that next to the object.

4th. A Prism is placed between the Eye-glasses and the Object-glass.

5th. A Prism is placed between the Eye and the Eye-glasses.

6th. A Plane Prism is placed between the Eye-glass next to the Eye, and that next to the object.

7th. Another Eye-tube is composed of an Eye-glass and a Prism with one surface, ground to a certain degree of convexity, which acts as a Prism, and as one of the Eye-glasses also.

8th. The Bull's Eye Eye-tube, which is composed of a Hemisphere, and acts as a convex lens with a

1782, in p. 44 of the *Phil. Trans.* for 1795.—Messrs. WATSON and TULLEY have assured me that no figure is more difficult to make than a perfect Plane.

prism;—this is more simple in its construction, is more perfect and lighter than any other prism Eye-piece—but even this is darker than an Huygenian eye-piece of the same magnifying Power.

From various trials of *Prisms* and *Specula*, I am convinced that it will be much easier to obtain a good Speculum than a good Prism—though either are extremely difficult to get perfect—and however perfect they may be, the diagonal vision is never so light, and seldom so distinct as the direct vision is—I say this, after a patient trial on the Planet Saturn, which suffered much more from the intervention of a Prism or Speculum than it did from using the Huygenian instead of a Single Lens Eye-piece: that is, the complexion of the Planet was diminished in brightness, and changed to a yellowish or greenish hue, and its features consequently became less striking on the Eye, and the Belts and Division in the Ring less marked;—the Observations I have quoted from Dr. Herschel respecting Single and Double Eye-pieces, apply very aptly to Diagonal and Direct Vision.—See Chapter V.

If a Diagonal Eye-tube, (No. 1.) made with a Speculum, is applied to an Achromatic Telescope of 5 feet focus, when an Huygenian Eye-tube magnifying 160 times is applied to it, the tube must be 2¼ inches shorter than is required with the same power with direct vision.

# CHAPTER XVI.

## MAGNIFYING POWER, AND HOW TO MEASURE IT.

An easy way of judging of the relative magnifying powers of various Eye-tubes and Lenses—is to hold them up about 12 or 18 Inches from the Eye, and 3 or 4 Feet from a window — that in which the panes of glass appear *least* magnifies *most* ;— or place two Candles nearly together—and hold the lenses about a foot from them, that in which the Candles appear nearest together magnifies most.

### TO ASCERTAIN THE MAGNIFYING POWER OF A TELESCOPE,

measure the diameter of the aperture of the Object-glass, or Speculum, and that of the little image of it which is formed at the end of the Eye-piece, the number of times the latter is less than the former is the Magnifying power.

To measure the diameter of the pencil of rays with great ease and accuracy, Mr. Ramsden*, about the

* The highest praise is due to the merits of the late *Mr. Jesse Ramsden*, for his ingenuity, liberality, and persevering endeavours to invent and perfect the various instruments used in Astronomy,

year 1775, contrived a clever little instrument which he called a *Dynameter* : for though when single lenses

Philosophy, and Mathematics; to produce which, he devoted all his time, and almost all the profits of his very extensive trade: in carrying on which, his anxiety was not (like the Razor-maker, who merely made his goods to sell,) to study and contrive how cheap he could make an instrument, and how dear he could sell it; his sole care was to make it as perfect as possible; he spared neither pains nor expense in forming an instrument, or bringing it to perfection; and his insatiable thirst for perfection, almost invariably, produced ultimate success. Without the least ostentation, pride, or reserve in his manners, he was polite, easy, and familiar to all that had business with him.

I have been favoured with the following Anecdote from such a source, that I can vouch for the authenticity of it.

"It was his custom to retire in the evening to what he considered the most comfortable corner in the house, and take his seat close to the kitchen fire-side, in order to draw some plan for the forming a new instrument, or scheme for the improvement of one already made. There, with his drawing implements on the table before him, a cat sitting on one side, and a certain portion of bread, butter, and a small mug of porter placed on the other, while four or five apprentices commonly made up the circle, he amused himself with whistling the favourite air, or sometimes singing the old ballad of,

> 'If she is not so true to me,
> 'What care I to whom she be?
> 'What care I, what care I, to whom she be!'

and appeared, in this domestic group, contentedly happy. When he occasionally sent for a workman, to give him necessary directions concerning what he wished to have done, he first shewed the

are used, the power of a glass is readily discovered by dividing the focal length of the object-glass by that of the eye-glass, in eye-pieces of the common construction, especially those of a negative focus, it is very difficult to measure in this manner; nor can it be done with any accuracy with those eye-pieces which are made for erect vision with four eye-glasses.

*The Dynameter* is principally composed of a fine micrometer screw, and a divided plano-convex glass; by means of which the image of the pencil of rays can be completely separated, and the diameter of it known to the greatest nicety. The wheel or head of

recent finished plan, then explained the different parts of it, and generally concluded by saying, with the greatest good humour, 'Now, see man, let us try to find fault with it;' and thus, by putting two heads together, to scrutinize his own performance, some alteration was probably made for the better. And, whatever expense an instrument had cost in forming, if it did not fully answer the intended design, he would immediately say, after a little examination of the work, 'Bobs, man! this won't do; we must have at it again:' and then the whole of that was put aside, and a new instrument begun. By means of such perseverance, he succeeded in bringing various mathematical, philosophical, and astronomical instruments to perfection. The large theodolite for terrestrial measurements, and the equal altitude instrument for astronomy, will always be monuments of his fertile, penetrating, arduous, superior genius! There cannot be a lover (especially of this more difficult part) of philosophy, in any quarter of the globe, but must admire the abilities of JESSE RAMSDEN!"

the micrometer is divided into two hundred equal parts, and a figure engraven over every fifth division, which is cut rather longer than the others; 1, 2, 3, and so on to 20: but adding an 0 to each figure, it will then read off, 10, 20, 30, and so on to 200. The Nonius is divided into 15 towards 0, and engraved 5, 10, 15; and 5 on the contrary side. Each division on the Nonius is equal to one revolution of the micrometer head, and 10 revolutions will bring the edge of the circle round it, and the tenth division on the Nonius to coincide.

The revolutions of the micrometer head will bring the edge of the circle round it, and the division on the Nonius, to coincide at 10: each division, therefore, is equal to the ten thousandth part of an inch.

Applying this little instrument to the eye-glass of a telescope, when adjusted to distinct vision at any distant object, and turning the micrometer head, the emergent pencil will begin to separate; and when the extreme edges are brought into contact, the number of divisions will shew the diameter of it in thousandths of an inch; then reduce the diameter of the Object-glass into thousands, and divide that sum by the diameter of the pencil, the quotient will be the real magnifying power. But as it is requisite for the emergent pencil of rays to be in the focus of the divided glass, a thin transparent piece of ivory, precisely one-tenth of an inch in diameter, is set in the sliding cover, to adjust for that distance, which

must always be done before it can be used with accuracy.

When this transparent piece of ivory is brought over the hole in the cover of the dynameter, and appears perfectly round, the Nonius will then be at 0, and is properly adjusted. Five revolutions of the micrometer screw will make a complete separation of the diameter of its aperture, which is one-tenth of an inch: and when the opposite sides are brought into contact, the Nonius will coincide at the fifth division of it, which is five two-hundredths of an inch; thus dividing each tenth of an inch into a thousand equal parts. Another method of discovering the magnifying power, is to set the telescope in such a position opposite the sun, that the rays of light may fall perpendicularly on the Object-glass; and the pencil of rays may be received on a piece of paper, and its diameter measured: then, as the diameter of the pencil of rays is to that of the Object-glass, so is the magnifying power of the telescope. Or, thirdly, a thin piece of mother-of-pearl, with a very acute angle two inches long marked thereon, and only one-tenth of an inch at its base marked thereon; the length being divided into ten equal divisions, making a visible line to each division, with a figure over it, these divisions will express or shew the hundredths of an inch: apply this scale to the eye-tube of the telescope, observe where the emergent pencil of rays fills up a certain space at or near

any of the divisions; multiply the diameter of the Object-glass into hundredths on the scale, and the quotient will be the magnifying power.

Neither of these methods will enable you to measure *Concaves*, but you may measure *Concaves* by comparing them with *Convexes*, in the manner I have mentioned to ascertain the relative powers of Lenses.

Before any of these methods of finding the magnifying power be made use of, remember to look through the tube, and observe carefully if some of the Object-glass be not cut off, and part of the original pencil intercepted by the *Stops* in the Tube, or Eye-pieces, &c., which frequently curtail the light of the Object-glass as effectually as a cap over the end of it would.

This is a very common trick, and will render your calculation on the whole aperture erroneous.

*To ascertain whether any of the Object-glass is cut off by the Stop in the Eye-tube*—adjust the Telescope to distinct Vision—then take out the Eye-glass, put your finger on the edge of the outside of the Object-glass, and look down the tube—if you can see the tip of your finger just peeping over the edge of the Object-glass none is cut off.

In all cases, the Magnifying power of Telescopes, or Microscopes, is measured by the proportion of the diameter of the original pencil, to that of the pencil which enters the Eye.

The following Observations on Deep Lenses were

given to me by a Gentleman well acquainted with the subject.

"*To determine the foci of very Small Lenses*—Get a Lens, the focus of which you know to be $\frac{1}{10}$th of an inch as nicely as it can be measured*—make a microscopic object of the image formed by it of some distant object, generally a window, and make it the Object-glass of a Telescope, (for such it is in its principle, though, instead of magnifying, it diminishes)—measure the size of the image with a micrometer, in the body of a compound microscope, and with which you can, without much difficulty, measure even the 35,000th part of an inch. Having once gained this point, it becomes an easy matter to determine the focus of any other lens, by comparing the size of the image formed by it with that of the 10th of an inch.

"Nothing is so common as to overrate the magnifying power of small Lenses—the very workmen who make them can seldom tell you this with accuracy; because they are obliged to make them shallow at first, and then to deepen them gradually out of one tool into another, till they have got them to the required focus; the tools themselves being perpetually liable to change their figure, indeed the very polishing will often destroy this altogether.

* A lens of much longer focus might be used, but would not be so convenient.

"The true magnifying power of a Telescope can only be obtained, by comparing the foci of the Object-glass and Eye-glass, and seeing how many times the one is contained in the other (which I apprehend to be the only method to be depended upon), consequently you never can know the magnifying power of your Telescope, till you truly know the focus of your Eye-glass: if it is a negative one, the diameter will be of use in enabling you to compare the size of the image formed by it with that of a single lens of known focus, and so obtaining the true power,—a dynameter will also do the work of a micrometer; indeed, it is nothing else, and used in the manner, and with the reservations described, that is, merely to determine *the foci of lenses*, will enable us to come at the true power of an Instrument."

"*A Plain and easy Method by which I could always discover the Powers of my Telescopes very readily, and with sufficient Accuracy.*

"At the distance of One or Two Hundred Yards from the Telescope, put up a small Circle of Paper of any determined diameter, an inch, for instance, upon a card, or any piece of strong paper, through which the light cannot be easily transmitted; draw two black parallel lines, whose distance from each other is exactly equal to the diameter of the small circle; adjust the Telescope to distinct vision, and through it view the aforesaid small circle with one

eye, and with the other eye, open also, view at the same time the two parallel lines.

" Let the parallel lines be then moved nearer to, or further from your Eye, till you see them appear exactly to cover the small circle viewed in the Telescope;— measure now the distance of the small circle, and also of the parallel lines, from your eye. Divide then the Distance of the former by that of the latter, and you will have the magnifying power of the Telescope required.

" Two other methods to determine, by experiment, the power of any Telescope are given in Dr. SMITH'S *Optics*, in the Notes upon Art. 109 and 485."—See *Appendix to the Nautical Almanack for* 1787, p. 44.

# CHAPTER XVII.

## OPINIONS

ON

## ILLUMINATING POWER,

AND OF THE COMPARATIVE POWERS OF REFLECTING AND ACHROMATIC TELESCOPES.

*N. B.—The Author publishes the following Opinions with very humble diffidence;—after all the care that he has taken to ascertain and write the Truth, he fears that he has given but an imperfect sketch of it; although the strong persuasion which he has, that he has, on some points, written the very Truth, has sometimes prompted him to express himself positively.*

THE Quality of a Telescope which should be first considered, is the degree of what Sir WM. HERSCHEL has termed its "*Penetrating Power,*" (see his Paper thereon at the end of this Chapter,) or what I call "*Illuminating Power;*" but this is seldom considered at all, because Nobody has attempted to explain its operation fully and fairly in

plain terms—which, therefore, I shall endeavour to make perfectly and easily intelligible to Everybody.

Opticians are often asked by their Customers, "How long is that Telescope?"

"How much does this Telescope Magnify?"—No *Vulgar Error* is more common than the notion, that if a Small Telescope magnifies as much, that you may see as much and as well with it, as with a Larger one—although such an idea is quite as absurd, as it would be to suppose that you can See as well with a little *Farthing Rushlight*, as with a Large *Argand's Lamp*.

Compare a Telescope of *Three* inches aperture, with a Telescope of *Six* inches aperture, while the Magnifying power does not exceed 60 in the Day-time, you may not perceive the effect of Illuminating power so evidently as you may expect—but use 100 by Day, or 160 by Night, it will appear much more evidently than you wish, and you will find that such is the advantage of Illuminating power, that objects not only appear brighter, and are more easily and more clearly visible, in the larger Telescope, but that with the same magnifying power, they appear larger also,—especially the Satellites of Jupiter and Saturn, and Small Stars.

This I have repeatedly observed, but never so strikingly, as in observing with my 7 feet Herschel's Newtonian, which has an aperture of $6\frac{3}{10}$ths inches,

and with my 3 feet Watson Gregorian, which has an aperture of $9\frac{3}{10}$ths inches, when I compared them at the Planets Jupiter and Saturn.

The following Tickets I have seen tied to Perspectives in a Sale Shop :—

*A Seven Mile Sight*, 3*s*. 6*d*.

*A Nine Mile Sight*, 4*s*. 6*d*.

*Eleven Mile Sight*, 5*s*. 9*d*.

For a queer unanswerable question*, often asked, is, " How far can I see with that Telescope?—can I see Two miles with it?"—I remember hearing this put to a shrewd son of GALILEO, who instantly replied, " *con strepito*," " Two Miles!—Sir, you can see 240,000 miles with it!!—Sir, you can see the Moon with it!!!"

* " Indeed the Fate of an OPTICIAN is very hard, if he be one that pretends to know any thing of the THEORY or PRINCIPLES of OPTICS; for People think to answer such questions as these, *What is the focus of the Lens? How many times does it magnify? What Field of View does it take in?* &c.

' Is to *him* not more difficile,
Than to a Blackbird 'tis to whistle.'

" And because it would be appearing in a bad Light, not to give the Querist some plausible Answer, tells him *the Lens is about* $\frac{1}{30}$*th of an Inch focus—That the Instrument magnifies* 200 *times*.—But whether his Responses are rigorously true, or not, he is secure from Detection, and he knows, that, with respect to such People, he can sufficiently satisfy them, with a

" *Crede quod habes, et habes.*"

BEN. MARTIN *on Micrometers*, 8vo. p. 3.

In estimating the comparative powers of Telescopes, People have never been taught, that the performance of these Instruments depends as much upon *Illuminating* Power, as upon *Magnifying* Power—it is therefore desirable to have a Scale for a guide, as to what is the needful proportion of *Illuminating* power to *Magnifying* power, for various Telescopes, and for the various Objects.

" Objects are viewed in their greatest perfection, when, in penetrating space, the Magnifying power is so low as only to be sufficient to shew the Object well—and when, in Magnifying Objects, by way of examining them minutely, the space-penetrating power (*i. e.* the Illuminating power) is no higher than what will suffice for the purpose; for in the use of either power, the injudicious overcharge of the other, will prove hurtful to perfect vision."—Sir W. H. in *Phil. Trans.* vol. xc. p. 81.

*When Illuminating power is in too high a degree*, the Eye is offended by the extreme brightness of the Object:—Sir W. H. informs us, in the *Phil. Trans.* for 1794, that " the strong light of the 20 feet Reflector (the aperture of which, I believe, was $18\frac{7}{10}$ths inches), in observing *Saturn*, was too great a fatigue to the Eye, which cannot bear to look at a very luminous Object for a long time together, for which reason, to observe Saturn, I chiefly used my 7 feet Newtonian."

*When Illuminating power is in too low a degree*,

the Eye is distressed by its endeavours to see what it cannot: therefore, it is extremely desirable, that when we wish to give the Eye all the assistance possible, to have the Illuminating and the Magnifying powers in due proportion, because we see best when we see easiest: — what this proportion is, depends upon the brightness of the Object; as that is luminous, the Magnifying power may be large.

" *α Lyræ*, I surmise, has Light enough to bear being magnified at least a Hundred Thousand times with no more than 6 inches of aperture."—See Sir Wm. H.'s *First Catalogue of Double Stars*, in the *Phil. Trans.* for 1782; and the *Obs.* on *α Lyræ*, in Chapter XX.

Sir Wm. H.'s observation applies very truly to *α Lyræ*—but not to the faint star that accompanies it — which is an extraordinary and unaccountable exception to the general rule, that objects admit magnifying power in proportion to their brightness, for this extremely faint object is visible only with a very high magnifier.—See my *Obs.* on *α Lyræ* in Chapter XX.

However beautifully perfect a Telescope may be, and however sharp its *Defining* power may be, its performance is limited by its *Illuminating* power, in like manner as the light of the sharpest Eye requires a certain degree of Light, without which, the proprietor of it can see no more with his Eye — than he can with his Nose.

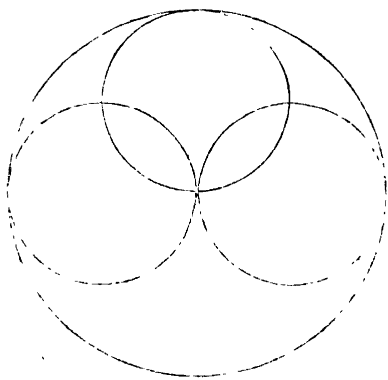
It has been asserted, that the Light, or "the Illuminating Power" of Telescopes, is as the squares of the diameters of the Apertures of the Instruments:—on this established dogma, I have formed my Table of Illuminating power.

As Opticians measure by *Tenths* of Inches, I have reduced the diameters of the various Telescopes into Tenths—and the Squares of these, (cutting off the last figure) I have set down as the relative Illuminating power of the respective Instruments.

An Optician informed me, that people commonly suppose, that a Telescope of 4 inches in diameter, will be twice as light as one of 2 inches in diameter—(that is to say, when the Magnifying power of the Instruments is the same,) instead of being Four times as light, as the squares of the diameters make it, as 16 to 4; that is to say, that when the magnifying powers are the same, that in the Telescope of 4 inches aperture, the pencil of Rays will be four times as large as it is in the Telescope of 2 inches aperture.

It is recorded, that the Proprietors of a Water Company, finding it convenient to borrow aid from another, requested permission to have a pipe laid on, the diameter of whose bore was 4 inches: this was granted, and being found not sufficient, a second pipe of similar size was requested, which was also granted; however, previous to laying down the second, a subtle calculator proposed, that as it would make a better job, and cost very little more

for a pipe of 8 inches than for one of 4 inches, that an application should be made for leave to exchange the two smaller pipes for the larger one, which was granted—the other party not being aware that they were giving double the quantity of water, or 8 times 8, or 64 square inches, instead of twice 16—or 32.



The above Diagram shews that a circle of 2 inches in diameter will contain four circles of 1 inch in diameter, and therefore, that the Illuminating Power of Telescopes is as the Squares of their Diameters.

A Pencil of Rays proceeding from a Telescope, makes a vivid and effective impression upon the Eye, in proportion to the Brightness and the Bigness of it—and of Telescopes, of which the Magnifying and

Illuminating powers are equal, objects will appear the brightest in that Instrument, of which the *Defining* power is most perfect, and that to a degree beyond imagination.

*Distinctness* is frequently misnamed *Light* and brilliance. A fine Telescope, is said to be remarkably light, because all the rays, by the mirror being ground perfectly true, unite at one point; and this uniform action produces the same strong effect as the equal bearing of every fibre of Captain Huddart's cable, of which every thread pulls.

In *Comparing of Telescopes* of various Diameters, so much depends upon Distinctness, or on what I have called their *Defining* power, that it is to no purpose, that their *Illuminating* and *Magnifying* powers are equal, unless their *Defining* power is equal also.

I have seen several Achromatics of more than 4 inches aperture — and several Gregorians of 7 and 9 inches aperture, with which, from the want of *Defining* power, I could not perceive a glimpse of the Division in the Ring of Saturn, which looked as dull as Lead—instead of shining bright like highly burnished Silver—as it does in a fine Achromatic Telescope, when the pencil of Rays is not less than $\frac{1}{10}$th of an inch in diameter.

Many Telescopes are good when their aperture is contracted a little, which are bad with the whole aperture.—See Chapter XX.

In Astronomical, as well as in all other concerns, *Truth* is the first *desideratim*:—our Telescopes only delude us, unless, like the Juryman's oath, they display the truth, and nothing but the truth. Astronomical amateurs should rather seek for *perfect* Telescopes, than *large* ones. What good can a great deal of bad light do?

In calculating the Illuminating power of Telescopes of various constructions, a Scale of *the comparative brightness* of the pencil of rays proceeding from various Instruments and various Eye-pieces, is as needful as the measure of the *bigness* of it; as is also, the requisite diameter of it for observing various Objects.

I think, that the Vision of my 5 feet Achromatic, which has an Object-glass of $3\frac{8}{10}$ths inches in diameter, is quite as bright as is useful for observing Saturn, when it magnifies 114 times—and that for observing planets, there is no use for a pencil of Rays from an Achromatic Object-glass being larger than $\frac{1}{30}$th of an inch in diameter, that is, the magnifying power which is given by setting down the diameter of the Object-glass in tenths of inches, and multiplying that sum by 3.—This is allowing an Achromatic, a pencil half as large again as that set down by Sir W. H. for observing Saturn with a Newtonian—for which he says, that a speculum of $6\frac{3}{10}$ths in diameter gave light enough with a power

of 287, consequently it was less than the 45th of an inch in diameter.

$$\begin{array}{r} 63 \\ 4\frac{1}{2} \\ \hline 252 \\ 31\frac{1}{2} \\ \hline 283\frac{1}{2} \end{array}$$

*For observing Planets,* our atmosphere will very seldom allow us to employ a greater Magnifying power than 200.

Assuming that the pencil of rays need not be larger than the 30th of an inch — and that the Magnifying power need not be larger than 200 times — if an aperture of $3\frac{8}{10}$ths inches admits a magnifying power of 114, what aperture is required for a magnifying power of 200?—The Rule of Three will tell us—

$$\begin{array}{l} \text{If } 114 \;:\; 38 \;::\; 200 \\ \qquad\qquad\;\; 200 \\ \hline 114)7600(6.6 \text{ inches aperture.} \\ \quad\;\; 684 \\ \hline \quad\;\; 760 \\ \quad\;\; 684 \\ \hline \quad\;\;\; 76. \end{array}$$

Thus it follows, that an Achromatic of $6\frac{6}{10}$ths inches aperture and 7 feet focus, and a Reflector of 10 inches aperture and 7 feet focus, are as large

Telescopes as the Atmosphere of this Country permits us to use.

*For observing Double Stars*—to shew them with a neatly circumscribed disk like a Planet — the pencil of rays from an Achromatic must not be larger than the 60th or 70th of an inch in diameter, that is to say, that which is given by setting down the diameter of the Object-glass in tenths of inches, and multiplying that sum by 6 or in some cases by 7 — that is, a power of about 180 for an Object-glass of $2\frac{7}{10}$ths inches in diameter, and of about 250 for an Object-glass of $3\frac{8}{10}$ths inches in diameter. — See Chapter XX.

What I have observed of Reflecting Telescopes, that the Makers should keep to certain lengths and certain apertures, applies still more strongly to Achromatics.

The greater the number made of the same diameter and the same focal length, the greater variety of combinations may be tried, as the concave and convex Lenses which compose their double Object-glass and the Crown and the Flint Glass, can be better adapted to correct the aberrations of each other; thus the more manufactured of one sort, the more easily and more perfectly each Object-glass may be made.

I have been told by a Working Optician of considerable experience, that when he makes *a couple of Dozen* Object-glasses of $2\frac{3}{4}$ths inches aperture, and gets *One* in which the spherical and chromatic aberrations are perfectly corrected, and that will define a

fixed star neatly—that he has quite as much luck as he looks for:—if it is so extremely difficult to find One really fine Object-glass of $2\frac{3}{4}$ths inches diameter, when you have Two Dozen to pick it out of—what must not be the difficulty of getting one of 6 inches in diameter? Why, the difficulty cannot be less than in the proportion of its Illuminating Power; and if with 72, the Illuminating power of the Object-glass of $2\frac{7}{10}$ths in diameter, it is 24—what will it be with 360, the Illuminating Power of the Object-glass of 6 inches in diameter?—The Rule of Three will tell us.

```
If 72  :  24  ::  360
                   24
                  ----
                  1440
                  720
                  ----
              72)8640(120
                  72
                  ---
                  144
                  144
```

So, If the Gentleman's reckoning that Opticians get only 1 fine Object-glass of $2\frac{7}{10}$ths diameter out of 24 is right—of 6 inches aperture we are only to expect 1 out of 120!

I fancy that I may say, without much danger of being contradicted, that not above 10 Achromatic Object-glasses of 6 inches Aperture have been made during the last 1825 years—therefore, if our future Opticians

are equally enterprising and equally industrious, it will take at least 18 Thousand 2 Hundred and 50 Years before Eye may hope to see a perfectly fine Object-glass of 6 inches Aperture. A long time to be sure—but might not the period be shortened, by persuading our Glass-Grinders to work faster?

It has been suggested (by what signifies who) that the art of Music might probably effect this—and that whereas Opticians have observed, that the muscles employed in making an Object-glass, sometimes become so exceedingly relaxed, that they will hardly do 5 days' work in 6—on the contrary, that their agility may be restored, and indeed so augmented by the continual stimulus of certain Sounds, that they may be excited to do 7 days' work in 6 days, and the said Object-glass be produced in $\frac{1}{7}$th less time—*i. e.* in 2.607 *Years 52 Days 1 Hour 42 Minutes 5 Seconds and $\frac{1}{7}$th of a Second less time*—*i. e.* that I may hope that Eye may hope to see a fine 6 inch Object-glass in only a little more than 15 Thousand Years!

Although the above calculation may not be so interesting to certain vulgar persons who are anon anon crying, on all occasions, "*cui bono?*"—it is presumed, that to some minute Philosophers it is quite as important and quite as useful as some of those reckonings, to which some pretenders to science have been indebted for no small portion of their Fame.

So we have ventured to insert it, and also the following anecdote illustrative of *a convenient effect of Music on Muscular Motion*,—presuming that we shall be

pardoned for such digression by hilarious and jocund Gentlemen who love to Laugh—and of those sad and silly Cynics who think that no man can ever be Wise, who is ever Merry, we beseech their Patience for a couple of pages more, when we promise again to become as matter-o'-factish as your Mathematician, and as melancholy as your Would-be-thought wise man sometimes thinks it becoming to pretend to be.

It is recorded, that during the preparation for a General Mourning, a certain Master of the Sheers, whose Customers were anxious to be

" Robed in the sable garb of Woe"

in due time, encouraged his workmen to proceed with their utmost agility, by the promise of a good Supper as soon as their work was done — and retired into his Parlour, which overlooked the Shop.

After finishing part of his pint and pipe, on looking at his men, he was electrified with astonishment to behold them, notwithstanding the promised reward of a capital Jollification as soon as they had done the Job—that their Arms were all moving simultaneously in an unaccountably irregular and whimsical manner; half a dozen stitches were followed by a general pause — another stitch or two — another — and again the threads were drawn with funeral slowness, and another general rest of Arms ensued — his Patience quite exhausted, he started up, and proceeded towards the scene of action; but before he had half reached it, his Legs were arrested by his Ears at the

same suit which had made captive the arms of his Men, and his progress was checked by a chord of slow Music—it ceased, his locomotive machinery was again ready for action, when his Legs, like as he had seen his men's Arms, were again suddenly arrested by another strain of Music—listening a little longer, he discovered, that the irregular action of his Artists arose from their listening to a neighbouring musician who was practising " The Dead March in Saul."

Bobs! cried our Master Tailor, what a glorious opportunity of proving *the Power of Music!* I'll pop in and tell *Signor Violino* what a grand effect his Playing has on our Working, and ask him to give them something " *Vite*"—" *Vivace*"—" *poco largo.*" The Knights of the Needle no sooner heard " *Moll i' the Wad,*" than their Ears insisted on their Elbows sympathising " *subito,*" and accordingly, they moved as nimbly as that of the *Chevalier del Arco*—

" Such sweet compulsion doth in Music lie," (MILTON.)

that they moved their Steel so fast, that many of them pricked their fingers. — Ah! Hah! cried Signor Violino, " *Spizzicato.*" Ah! Hah!—" *dolce, dolce,*" we must ply them with one " *poco presto*"—we must proceed " *con discretione*"—" *con dolce maniera,*" let us tash away in one Grand March: during his performance of this, the " *Tutti*" took their stitches so suddenly and so long, that each man marched his needle plump against his neighbour's Elbow—till the Chevalier's Harmony was accom-

panied by as much Discord, as the unconcatenated sounds of the *Der Freischütz* itself.

The *following* is "*the Glass-grinder's Roundelay,*" from a copy in my possession; to which there is affixed neither the name of the writer nor the composer; therefore, it is quite impossible to imagine at exactly what period it was produced. Whether it was composed by Galileo, Huygens, Ramsden, Dollond, "*n'importe,*" if, by the continual chaunting of it, Opticians can do 7 days' work in 6, and make a fine Object-glass of 6 inches aperture in only a trifle more than 15 Thousand Years.—May be you don't mind who made it, Gentle Reader, much more than I do.

THE GLASS-GRINDER'S ROUNDELAY.



"INVESTIGATION OF THE CAUSE OF THAT INDISTINCTNESS OF VISION WHICH HAS BEEN ASCRIBED TO THE SMALLNESS OF THE OPTIC PENCIL. BY WILLIAM HERSCHEL, LL.D. F.R.S.

[Read June 22, 1786.]

"SOON after my first essays of using high powers with the Newtonian telescope, (see page 134 preceding,) I began to doubt whether an opinion which has been entertained by several eminent authors, " that vision will grow indistinct, when the optic pencils are less than the 40th or 50th part of an inch," would hold good in all* cases. To judge according to so rigid a criterion, I perceived that I was not entitled to see distinctly with a power much more than about 320, in a 7 feet telescope, which bore an aperture of $6\frac{3}{10}$ths inches; whereas, in many experiments on double stars, I found myself very well pleased with magnifiers that

* This Rule did hold good in Reflecting Telescopes in *All* cases, till Dr. H. turned the attention of Astronomers to Double Stars, the intense intrinsic brightness of some of which will admit of much more magnifying power than any of the Planets—many Stars will not appear sharply and distinctly defined until the pencil of Rays is less than the 70th of an inch in diameter; some require it even less than that, however perfect the Telescope.

The Eye is not sufficiently stimulated by Saturn with a pencil less than the 40th of an inch, *i. e.* a power of about 250, with a 7 feet Newtonian, with an aperture of $6\frac{3}{10}$ths inches.—W. K.

far exceeded such narrow limits. This induced me, as it were, by way of apology to myself, for seeing well where I ought to have seen less distinctly, to make a few experiments on the subject of the diameter of optic pencils. It occurred to me, that an opinion which limits them to any given size cannot be supported by theory, which does not determine on subjects of this nature, but must be decided, like many other physical questions relating to matters of fact, by careful experiments made upon the subject*."

EXPERIMENT WITH THE NAKED EYE. P. 501.

"*Exp.* 1.—Through a very thin plate of brass I made a minute hole with the fine point of a needle; its magnified diameter, very accurately measured under a double microscope, I found to be .465 of an inch, while, under the same apparatus, a line of .05 in length gave a magnified image of 3.545 inches. Hence I concluded, that the real diameter of the perforation was about the 152d part of an inch. Through this small opening, held close to the Eye, I could very distinctly read any printed letters on which I made trial."

MICROSCOPIC EXPERIMENTS.

"N. 8.—This gave a pencil of 2173d part of an inch, with which I could count, or rather successively

* *Phil. Trans.* vol. lxxvi. p. 500.

see, the bristles on the edge of the wing of a fly very well; the field, on account of the great power, not taking in more than two large and a small one at a time." p. 503.

*Exp.* 10.—It appeared that with equal pencils, unequal degrees of distinctness may take place, and Dr. H. very rationally deduces from this, "that a certain proportion of aperture is necessary to a given focal length of an object lens or speculum; and that a failure in this point might probably bring on that indistinctness which has been ascribed to the smallness of the pencils." p. 504.

"I shall, however, now proceed just to hint at a few inferences that may be drawn from these related experiments; as, upon a mature consideration, we may find reason to believe they point out a cause of indistinctness of vision hitherto never noticed by optical writers; and which, when properly investigated, cannot but influence, and in some respects contribute to the improvement of our theories in optics. For admitting that *every Object-Glass or Speculum, whose aperture bears less than a certain ratio to its focal length, will begin to give an indistinct picture,* it will follow, that while former opticians have been endeavouring to diminish the aberrations arising from the spherical figure, and the different refrangibility of rays, by increasing the focal length, they have been unaware of exposing

themselves to the consequences of the cause of indistinctness here pointed out. And till its influence shall be well ascertained and brought to a proper theory, we must suspect that such tables as those which are given in our best authors on Optics, pointing out an aperture of less than 6 inches for a glass of an 120 feet focal length (or a ratio of 1 to 240), must be far from having that degree of perfection which may yet be obtained. No wonder that telescopes, made according to theories or tables, where one of the causes of indistinctness is unsuspected, and therefore left out of the account, can bear no smaller pencil than the 40th or 50th part of an inch!

"If then, on one hand, by increasing our apertures we certainly run into great imperfections, we ought, nevertheless, to consider what dangers, on the other, we may incur by lessening them too much."—*Phil. Trans.* vol. lxxxvii. p. 506.

As I have said—in 9 nights out of 10, the Atmosphere prevents the application of a higher power for *Planets* than 200—double that is enough for defining almost any *Double Star*—and that with these objects, and with these powers, the vision from an Object-Glass of 6, or a Speculum of 10 inches in diameter, is as vivid as the Eye wishes;—this is extremely important data, because the less the diameter of the Object-Glass or Speculum, the greater is the chance of its material being good, and of its figure being good—and the facility of using it.

An Object-Glass of 6 inches aperture may be made of 10 or 7 feet focus, and may perhaps be worked perfectly; but the errors proceeding from aberration arise in such an extremely high ratio in larger Apertures, that it is hardly to be hoped that human ingenuity will ever produce an Achromatic of larger Aperture, possessing that perfect degree of *Defining* power, which is indispensable for Planetary observations:—there is a limit to the perfect manipulation of Lenses, they cannot be worked of larger diameter than Specula; and Sir W. H. observes, in vol. lxxxiv. of the *Phil. Trans.* that " the maximum of distinctness is much easier obtained in a Metal of 6 inches in diameter than it is in larger ones."

Specula are dear in proportion to the difficulty of working them, which arises in a high ratio to their diameter, as the following prices do, for a Metal of $6\frac{3}{10}$ths in diameter: the price put down in Mr. Tulley's Catalogue, see page 83, is £105.

| | |
|---|---|
| For a Metal of 7 inches | £126 |
| For ditto of 9 inches .. | 210 |
| For ditto of 10 inches .. | 315 |

The following is an abstract of the account published by the Astronomical Society of London, of

FRAUNHOFER'S ACHROMATIC.

" The Tube is 13 feet long, constructed of Deal in the strongest manner, and overlaid with Ma-

hogany, so worked that it appears like a tube of highly burnished Copper. The Object-Glass and Eye-Glasses are set in metal frames, and provided with adjusting screws, for the purpose of bringing the axis of the Glasses into one straight line. The diameter of the Object-Glass is 9 Paris inches.

"The most perfect motion round the Polar axis is produced by means of Clock-work, which, when set in motion, the Star will remain quietly in the centre of the field*, even when magnified 700 times. At the same time, there is not the least shake or wavering of the Tube; and it seems as if we were observing an immoveable Sky. This instrument has 4 Eye-pieces, the least of which magnifies 175 times, and the largest 700.

"Schröter's 25 feet Reflector is decidedly very inferior to this Instrument.

"This masterpiece was sold to us by Privy Counsellor Von Utzschneider, the chief of the Optical Establishment at Munich, for £950, a price which only covers the expenses which the establishment incurred in making it.

"W. Struve."

Dorpat, 1st Jan., 1825.

* This movement is a very great advantage, because it is highly necessary that, while we are adjusting a Telescope to distinct vision, the Object should be in the centre of the field of view, that being the most perfect part of the field.—Read Chapter X.

See Professor STRUVE'S *Letter* to FRANCIS BAILEY, Esq. President of the Astronomical Society of London, on Fraunhofer's *Telescope*, at the Observatory at Dorpat.

Professor S. says that this Instrument is superior to *Schröter's* Reflector, because it shews more Small Stars;—that is only evidence of its *Illuminating* power, but he has not adduced any proof of its *Defining* Power.

I have seen, and may be, Gentle Reader, your Eye has seen some very handsome and some very very large Telescopes, that would shew lots of Small Stars, which were, nevertheless, bad enough—and would not sharply define any of the Planets.

I do not pretend to give any infallible Rules as to what must be the diameter of a cone of rays, coming from *a Gregorian Reflector*, to be equal to, *i. e.* to paint as vivid a picture on the retina, as that transmitted by *an Achromatic Refractor*.

The Table at the end of this Chapter approximates as nearly to the truth as I have been able to calculate, according to the estimate that the Light of Telescopes, of similar construction, is in proportion to the squares of the diameters of their Apertures.

I think that the Light transmitted by the Object-Glass of an Achromatic, is at least twice as vivid as that reflected by the Speculum of a Reflecting Telescope, that is to say, a cone of Rays of $\frac{1}{20}$th of an inch in diameter from an Achromatic, will make as

strong an impression upon the Eye, as a cone of Rays from a Reflector of double that diameter — this reckoning I made with the Huygenian Eye-tube for the Achromatic.

The Newtonian Telescope, I think, reflects rather more Light than either the Gregorian or Cassegranian, which I believe are upon a par.—See Sir *Isaac Newton's* Paper in page 155; and read the whole of Chapter IX.

Before I had any idea of endeavouring to lay down a Scale of the proportions of Illuminating and of Magnifying power to each other, in Telescopes of various constructions, and their application to various objects; I found on trying my *Herschel* 7 feet Newtonian with a power of 213, that it gave me about the same degree of Illumination of Saturn, as my 5 feet Achromatic did with 160—and that 250 was quite as much as my Eye liked with that Newtonian, as 190 was rather beyond the maximum with the 5 feet Achromatic— this corroborates the accuracy of my estimate of the relative brightness of the pencil of rays from an Achromatic and from a Newtonian, and proves that it approximates to the truth—for as the Illuminating power of the 5 feet is 144 — and of the Newtonian 396—or, as its pencil is required to be double the diameter of that from the Achromatic, we will reckon it 198, the Rule of Three will give us what Magnifying power a Telescope, with an Illuminating power of 198, will bear, to be as bright and distinct

as a Telescope with an Illuminating power of 144 is with 160.

If 144 gives 160, what does 198

```
              198
              160
            -----
            11880
            198
            -----
     144) 31680 (220
          288
          ---
           288
           288
           ---
```

and if 190 is rather beyond the maximum of magnifying power for Saturn in the 5 feet — what is it in the 7 feet?

If 144 gives 190, what does 198

```
               198
               190
             -----
             17820
             198
             -----
      144) 37620 (261
           288
           ---
            882
            864
            ---
             180
             144
             ---
              36
```

261 is rather beyond the maximum of Magnifying power for Saturn, in the 7 feet Newtonian.

The powers 213 and 250 are produced by the same Huygenian Eye-tubes, which applied to the 5 feet Achromatic, produce 160 and 190—the Focal length of the 5 feet Telescope rather exceeds its nominal length; and the Focal length of the 7 feet is rather short of what it is denominated.

The facts related above, support my assertion, that the Pencil of Rays from a Newtonian Reflector is about half as effective as that from an Achromatic—and according to that reckoning, that the effective Illuminating power of the 7 feet Newtonian, with a Speculum of $6\frac{3}{10}$ths inches in diameter, is to the 5 feet Achromatic, with an Object-Glass of $3\frac{8}{10}$ths inches in diameter—as 198 to 144, therefore the Former is by full ¼th a more powerful instrument than the Latter.

Dr. Maskelyne states, in the Appendix to the *Nautical Almanack* for 1787, that to be as light,—the aperture of a Common Reflecting Telescope must be to that of an Achromatic Telescope as 8 to 5—but he does not mean as the Squares of those numbers—*i. e.* as 64 to 25.

I have reckoned in my Table of the Comparative Illuminating Powers of Achromatic and Gregorian Telescopes — that an Achromatic of Two inches aperture, is about upon a par with a Gregorian Reflector of Three inches aperture, calling the Illu-

minating power of the former 40, and of the latter 90:—if the defining power of the Gregorian be equal to that of the Achromatic, the Reflector ought to be the more effective instrument.

I compared a 5 feet Achromatic with a double Object-Glass of $3\frac{8}{10}$ths inches in diameter, and whose Illuminating power I therefore call 144, with a Gregorian Reflector of 2 feet focus and $5\frac{3}{10}$ths inches in diameter, and Illuminating power 280—therefore, when the Magnifying power of the two Instruments was equal, the pencil of Rays reflected from the Speculum was very nearly double the diameter of that transmitted by the Object-Glass:—these Instruments were equally excellent, and their Magnifying powers were equal; I tried them at some Gilt Letters, on a board, at about half a mile distant, which were very well illuminated: the Reflector was equal, if not superior to the Achromatic.

I had no opportunity of comparing these Instruments at either a Star or a Planet, or I suppose that the Achromatic would have been superior in shewing these Small Stars, like that which accompanies the Pole Star, &c.

On the 2d of October, 1822, between nine and ten in the evening, I compared a celebrated 7 feet Achromatic with an aperture of 4 inches, with an excellent Gregorian of 3 feet focus with an aperture of 7 inches, which was contracted to 6 inches;—with the Achromatic, with all its aperture and a power of

240, Saturn was not so sharply defined as when the Object-Glass was contracted by a ring of pasteboard to $3\frac{8}{10}$ths — the Gregorian Telescope shewed the Belts on the Body, and the Division in the Ring of Saturn, more distinctly than the Achromatic, especially with high powers:—this 7 feet Achromatic shewed the Small Star, near the Pole Star, uncommonly plain.

On the 9th May, 1824, I compared a fine 44 inch Achromatic of $2\frac{7}{10}$ths aperture, with a Gregorian Reflector of 12 inches focus and of 4 inches aperture: — *Jupiter* did not appear so white in the Gregorian as it did in the Achromatic; yet two Opticians who observed it, agreed with me, that the Belts were more distinctly visible in the Gregorian—however, we saw the Small Star, near the *Pole Star*, in the Achromatic, but could not perceive it with the Reflector, which, with a power of 250, defined *Castor* like two little moons; giving them less diameter than they had with that power in the Achromatic—and increasing their separation.

1824, Dec. 20th, half-past 9—*Saturn* very near to the Meridian, with the above-mentioned Gregorian, and a power of 130, the division in the Ring as visible as with my fine 30 inch Achromatic, which has a double Object-Glass of $2\frac{7}{10}$ths inches in diameter.

I expected that the Belts of *Jupiter* and *Saturn*, and the Division in his Ring, would be easily seen

in proportion that a Telescope shews those Planets of a White colour—*i. e.* as the contrast between the colour of the Body and the Belts upon it, is greater: however, in the trial recorded above, the Achromatic shewed these Planets whiter than the Reflector; yet the Belts of *Jupiter,* and the Division in the Ring of *Saturn,* and Day objects, appeared more distinctly in the Reflector than in the Achromatic Telescope.

Mr. Ben. Martin tells us, that "it is by *Reflected Vision* only that an Optical instrument truly *Colourless,* can possibly be constructed."—B. MARTIN's *Optical Essays,* p. 42.

This is fortunate, because *Reflecting Telescopes* have been made good by several Amateurs—*Achromatic Refractors* are a complicated work, which is very seldom produced perfect by even the most experienced and most expert Opticians: without any reflection on refractors, they deserve the misnomer which a Showman gave to his Telescope—"it is *a Refractory Telescope.*"

Achromatics are inferior to Reflectors for Day purposes, and for observing Planets, but when very perfect they shew *Small Double Stars* better than the generality of Gregorian Reflectors.

I am disposed to attribute this failure of the defining power of the Gregorians when turned to Small Stars, merely to their not having been finished with due attention for that especial purpose,—or to their not being exactly in Adjustment:—great care and

pains have of late years been bestowed on Achromatic Telescopes; but Reflectors for the last twenty years have almost entirely neglected.

For the following information, I am indebted to Mr. CUTHBERT, maker of Reflecting Telescopes, &c.—See pp. 95 and 169 of this work.

"DEAR SIR,

"IN compliance with your wish to know my method of adjusting the small metals of Reflecting Telescopes, I beg leave to make the following communication:—

"I place the ball of a Mercurial Thermometer at about one hundred yards distance, and in that situation that the Sun may shine on it about 5 or 6 o'Clock in the Evening,—the Atmosphere gets more quiet towards Night.

"When I view this Ball with the Telescope, to be adjusted when the Sun shines upon it, if the Figure of the Metals are good, and in good adjustment, I see a perfectly round and well-defined artificial Star.

"To ascertain whether the small metal is in adjustment, I separate it from the large one by turning the adjusting screw back about two turns; the spot of light will then increase, and a black spot appear exactly in the centre, (if the metal is in adjustment,) if not, it must be made to fall exactly in the centre, by screwing in the screw which is on the side the

black spot is inclined to; and unscrewing the opposite one; this must be effected by small quantities of a turn at a time, and then examined again—the eighth of a turn will be found to make a great alteration; I mean one of the Three Screws which press against the back of the Small Metal: the centre Screw need not be altered.

"By a few trials, it will be found easy to adjust the Small metals of a Reflecting Telescope; I find by experience this mode superior to adjusting by a Star at Night.

"Hoping, Sir, this communication will prove useful,

"I remain, Dear Sir,

"Yours, most respectfully,

"JOHN CUTHBERT."

22 Bishop's Walk, Lambeth,
June the 9th, 1825.

Of those *Double Stars*, of which one is *Blue*, or *Reddish*, &c. the colour appears of deeper tone in Reflecting Telescopes, and increases in tone as the Aperture of the Instruments is increased.—See *Obs. on Rigel*, in the Chapter on *Double Stars*.

The dusky Red colour which *Dr. Herschel* mentions, as being the complexion of the Small Star accompanying *Rigel*, was more evident in my 7 feet Newtonian than in my 5 feet Achromatic; but the Larger Star was better defined, and the Small Star

was more neatly separated from the Large Star in the Achromatic; I attributed this to the Newtonian not having been then in very nice adjustment:—the uncertainty of the adjustment in Newtonian Reflecting Telescopes which have wooden Tubes, I have mentioned in page 125.

The failure of Reflectors in shewing the small Stars which accompany *Rigel*, the *Pole Star*, &c. can only be attributed to their want of Defining power—yet Reflectors have only the difficulties of Workmanship to overcome, and those only in half the degree which Achromatics have.

In *a Double Object-Glass*, there are four surfaces which must be very exactly figured; and their curves must be very exactly proportioned to each other, and they must be very exactly centred:—in a *Newtonian*, there are only Two surfaces,—Refractors have also to contend with the great impediments which arise from the uncertain quality and the imperfections in the materials they are made of.

It is greatly to be regretted, that the difficulty of obtaining Glass free from veins, &c. and sufficiently homogenous, and the difficulty of working it to a perfect figure, have hitherto been insuperable obstacles to the extending the Apertures of Achromatics beyond $3\frac{8}{10}$ths Inches:—I don't believe that there are half-a-dozen larger in the Universe, that will define large Stars, or Planets, perfectly well with the whole of their Aperture.—See page 17.

I am perfectly aware of the pompous accounts published of the large Apertures of the Object-Glasses lately made; but not any proof has been produced that their effect is in proportion to their dimensions.—See p. 267.

*Illuminating* power, unaccompanied by *Defining* power,—is as useless as the Sword of a Giant of twelve feet high, would be in the grasp of a Gentleman of three feet high.

If good Glass be obtained, it seems that it will still be twice as difficult to obtain an Achromatic of 5 inches Aperture, as it is to make a Reflector of 7 inches.—See *Table of the Comparative Illuminating Power of Achromatics and Reflectors,* at the end of this Chapter.

As to Reflectors being troubled by *Tremours,* which Achromatics are free from, if such an assertion was true half a century ago, when they were suspended on miserable ricketty Stands, — it is not true now,—on the improved Stands now in use, they are as steady as Achromatics.

The Paper written by Sir Wm. H. in the *Phil. Trans.* "on the Power of Telescopes Penetrating into Space," of which I have given an Abstract at the end of this Chapter, will explain the nature of what I have called "*Illuminating Power,*" which, however, I will endeavour to further illustrate.

In no instance is the effect of Illuminating Power

more evident than in examining particular parts of the *Moon*, with various Apertures.—See *Obs.* on the *Moon* in Chapter XIV.

The Small Stars, near the *Pole Star*, and near *Rigel*—the Division in the *Ring of Saturn*—and distant objects in the Evening, which are distinctly seen with a 5 feet Achromatic of $3\frac{8}{10}$ths inches Aperture, and an Illuminating power of 144, are scarcely visible in a $3\frac{1}{2}$ feet, with an aperture of $2\frac{7}{10}$ths inches, and an Illuminating power of 72—and with a $2\frac{1}{2}$ feet, with an Illuminating power of 40, are generally invisible: supposing that the several Instruments are equally perfect, and have precisely the same Magnifying power applied to them.

With objects which are well illuminated, in the *Daytime*, the advantage of Illuminating power, beyond a very limited degree, instead of being so great as People expect, is not only useless,—but offends the Eye—for instance, affix the Day eye-piece, usually put to a $3\frac{1}{2}$ feet Achromatic, to a $2\frac{1}{2}$ feet Achromatic, with an Object-Glass of $2\frac{7}{10}$ths in diameter, this will make it magnify about 30; point it to a printed paper about 2 or 3 hundred feet distant, you will be able to see the letters, as well when the aperture of the Telescope is limited to $1\frac{5}{10}$ths as with $2\frac{7}{10}$ths—because the pencil of rays from the smaller aperture paints as vivid a picture upon the retina as that from the

larger — this proves that for Day purposes there is no use in the pencil from an Achromatic being more than $\frac{1}{20}$th of an inch in diameter :—but if you put on a magnifying power of 60—or try the experiment in the evening, you will then find the advantage of the larger Aperture.

This Law of a certain proportion of the diameter of the pencil to the nature of the object, governs in all cases—there is no advantage in its being larger than a certain diameter: a Scale of what that is for various Objects, would be a great acquisition, as the difficulty of obtaining the curves which produce perfect defining power, increases in an extremely high ratio to the increase of the Aperture of Telescopes, as does also the expense of those Instruments, and the difficulty of using them on account of their becoming longer, &c.

*To ascertain the Illuminating Power of Telescopes,* try them at the objects above mentioned, or in the close of the Evening, at a Printed Bill, composed of Letters of various sizes :—in the 5 feet Telescope some Small Letters will be legible, which are hardly discernible in the 3½ feet, and in the 2½ feet are quite undefinable.

*Illuminating Power* is most accurately estimated when it is most wanted, *i. e.* on minute objects, and such as are badly lighted up : the advantage of a Large Telescope is most obvious if the comparison is made at the close of day : as darkness comes on,

the use of Illuminating power will become more evident.—See Mr. TULLEY's *Letter* in the Chapter on *Cassegranian Telescopes*, page 165—and Sir W. H. on *Penetrating Power.*

An excellent *test to determine the relative Illuminating power,* and Defining power, of various Instruments, is the Division in the Ring of Saturn—and the Immersion and Emersion of the Satellites of Jupiter—this latter was the proof which the Astronomer Royal, Dr. Maskelyne, made use of for ascertaining the Light of his Telescopes: his experiments I have related in page 108.

When the Immersions and Emersions of the Moons of Jupiter, are seen at the same instant by two Instruments, we conclude, that their Illuminating power is the same—*i. e.* if they are charged with exactly the same Magnifying power, and they define the Planet with equal sharpness:—of Telescopes of the same size, that is the best, of which the Defining power is best—which is demonstrated by the Immersion being visible latest, and the Emersion soonest.

IN RECORDING THE PERFORMANCE OF TELESCOPES,

the Aperture,—the Focal Length,—and the Magnifying power of the Instruments, should be accurately stated;—also the distance of the Object from the

Telescope in the Daytime— and from the Meridian at Night—and those who are really anxious to be very accurate, will also note the temperature of the Thermometer,—the height of the Barometer,—the position of the Wind,—the Place where,—and the Hour, the Day of the Month, and the Year, when the Observation was made.

As I have before said, a Gregorian Reflector cannot so easily be made very good, if the focal length of its large Metal be less than 4 diameters of its Aperture; so an Achromatic Telescope cannot be made so perfect, as it is capable of being made, unless a due proportion is observed between the Focal length and the diameter of its Object-Glass.

*To apply Magnifying power to the utmost advantage*, and in due proportion to the Illuminating power obtained by increasing the aperture of an Achromatic Telescope, the length of the focus thereof must be increased—but in what proportion, if it has ever been proved, has never been published;—the proportion of Aperture to Focal length varies in almost every different-sized Telescope, as the Reader will perceive by a glance at the *Table of Achromatics*, p. 24.

I think that the 30 inch Achromatic, which has an Object-Glass of 2 inches in diameter, is more frequently entitled to the appellation of *Achromatic*, than any of that length, and which have an Object-Glass of larger diameter.

My own experience of the performance of Achromatics is, that an aperture of $2\frac{7}{10}$ths requires a length of at least 44 Inches, and would be a much more effective instrument if made 5 feet.

I had 3 Achromatic Telescopes, with an Aperture of $2\frac{7}{10}$ths inches, which were only 30 Inches focus; and I have every reason to think, that the utmost care was taken by the makers to produce as perfect an instrument as possible—however, only one of them could shew ε *Bootis* well—which I saw very distinctly with a *Pancratic* Eye-tube, which magnifies 270—but with that Telescope I could neither see the small Star, near the Polar Star, nor the small Star which attends *Rigel;*—another would shew the two latter, but not so easily as a $3\frac{1}{2}$ of the same aperture—but would not shew ε *Bootis* with any power;—the Third was very shy at any of these Objects—nor for Terrestrial purposes, were any of these 30 Inches equal to a good $3\frac{1}{2}$ of the same Aperture;—although they performed pretty well, and might satisfy unexperienced Amateurs, whose uneducated Eyes have had no opportunity of comparing them with a fine telescope of the like Aperture, of longer focus.

The advantage—the necessity, I may say, of a certain *proportion between the Focal length and the aperture of a Telescope,* is learned by the fact—that the double Object-Glass of an Achromatic Opera-Glass, which is of an Inch and a half Diameter,

from being of not more than four inches focus, will not bear a higher power, with distinctness, than 5 times—the Object-Glass of a Two feet Achromatic, which is no larger, will magnify 100 times.

The 30 Inch Telescopes above mentioned, with Object-Glasses of $2\frac{7}{10}$ths inches in diameter, were all more perfect when limited to 2½ or to 2 inches, with the whole Aperture of $2\frac{7}{10}$ths inches, the edge of the Moon and of Jupiter, was tinged with a *Blueish*, or *Greenish*, or *Yellowish* fringe—which varnished when I limited them to 2 inches;—but no advantage appeared to be gained by any further contraction;—therefore, I am induced to offer a conjecture, that for a Focal length of 30 Inches, that an Aperture of 2 inches—*i. e.* an Illuminating power of 40—approximates very nearly, if not quite, to the standard required:—if this be the Basis of proportion for other Achromatic Telescopes, the general notion that the Apertures of Achromatics are not increased in the ratio that their Focal length is increased, is extremely erroneous.

Opticians have informed me, that their Customers frequently ask, "Why a 5 feet Achromatic has not an Aperture of 4 Inches? it is twice the length of a 2½ feet, and therefore, should be made with twice as large an Aperture to have a due degree of Illuminating power." Now the fact appears to be, that, if Illuminating power is as the squares of the Diameters of the Apertures, that $3\frac{8}{10}$ths inches, the usual dia-

meter of the Object-Glass of a 5 feet Achromatic, is a much larger aperture in proportion to 5 feet focus, than 2 inches is to 2½ feet:—*i. e.* reckoning the squares of the diameter of the apertures in Tenths of inches, and cutting of the last figure, thus, 40 for the 2½ feet, and 144 for the 5 feet;—it appears that the 5 feet, as usually made, with an aperture of 3⁸⁄₁₀ths inches, has nearly twice as large an aperture in proportion to its focus as the 2½ feet, which has an aperture of 2 inches—and with Double the focal length, has very nearly Quadruple the Illuminating power.

If an Illuminating power of 40 is the proper proportion for an Achromatic with a focal length of 30 inches—*the Rule of Three* will tell us what should be the proportion in any other Telescope. Thus—for an Achromatic of 44 inches focus, whose aperture is commonly 2⁸⁄₁₀ths inches, and consequently whose Illuminating power is 72.

| | an Illuminating Power of | | Inches focus. | | an Illuminating Power of |
|---|---|---|---|---|---|
| If | 40 | requires | 30 | what will | 72 |

```
                 72
                 30
               ----
            40)2160(54 Inches.
               200
               ---
                160
                160
                ---
```

For a 5 feet Achromatic, with an aperture of

$3\frac{8}{10}$ths inches, whose Illuminating power is 144, and whose focal length is commonly 63 inches.

If 40 requires 30, what does 144

$$\begin{array}{r} 144 \\ 30 \\ \hline 40)4320(108 \text{ Inches.} \\ 40 \\ \hline 320 \\ 320 \\ \hline \end{array}$$

Thus, if an Achromatic of $2\frac{1}{2}$ feet Focus, is best with an Aperture of 2 Inches, and an Illuminating power of 40, an aperture of $2\frac{7}{10}$ths inches should have a focal length of 4 feet 6 inches:—an aperture of $3\frac{8}{10}$ths inches a focal length of 9 feet.

These calculations correspond very nearly, but are still short of *the length of which Achromatics were originally made, i. e.* Telescopes of $2\frac{7}{10}$ths aperture were formerly of 5 feet focus, and those of 4 Inches aperture were 10 feet focus; now this proportion was adopted when the only consideration in making an Achromatic telescope was, how to correct the chromatic and spherical Aberrations in the most perfect manner, so as to render the vision in a Refractor as good, and that objects might appear as perfectly of their natural colours, as they do in a Reflector,—this accomplished—the next desideratum was to make Refractors as short as Mr. Short made his Reflectors, and that they might be used as easily as

possible; therefore, the makers contracted the Focal lengths of the Instruments, finding that for ordinary uses, and ordinary eyes, that this might be done without much injury to their performance.—What was called THE 17 INCH ACHROMATIC, was made at this time—this had a treble Object-Glass, with an aperture of 2 inches, and was mounted on a portable rackwork stand, which packed within the tube; and the whole was a very ingenious apparatus.—I have had Four of these Telescopes, three of which were very indifferent—the other was inferior to the 30 inch of the same aperture, which are sold at £10. 10*s.*—these little ineffective Dumpies were charged at £15. 15*s.*—they were extremely difficult to make good, and for several years have been almost entirely given up.

The longer the focus of the Object-Glass, the less will be the chromatic and spherical aberrations of it, and the larger may be the Eye-glasses, and consequently, the larger and flatter the field of view—thus it appears, that (especially for Celestial observations) the long Achromatic Telescopes of the original proportions, were much more perfect and more powerful than the short Instruments now usually made.

When the aperture of my 5 feet Achromatic is limited to $2\frac{3}{4}$ths inches, with 250, I can see the two stars of ε *Bootis* perfectly well—which cannot be seen well with a $3\frac{1}{2}$ feet telescope of $2\frac{3}{4}$ths aperture—this is from the longer focus of the 5 feet.

Well might *Dr. Maskelyne* say, that "Telescopes of *Sir Isaac Newton's* construction perform most excellently in the *Minutiæ* of Astronomy, especially if small Apertures and long Foci are made use of."—See *Supplement to the Nautical Almanack* for 1787, p. 42.

Vision is vivid in an *Achromatic*, in proportion as it is derived from a due degree of original power from the Object-glass—with the same Magnifying power, and same Aperture, *small Stars* appear larger and brighter, and the division of *Double Stars* is greater and more perfect.

I was surprised to find, on comparing *Achromatic Telescopes of different lengths*, at objects in the Daytime at about a mile and a half distant, that the vision of my 5 feet Telescope, of $3\frac{8}{10}$ths inches aperture (see page 47), when its aperture was contracted to $2\frac{7}{10}$ths inches, compared with a $3\frac{1}{2}$ feet of the same aperture, and with a $2\frac{1}{2}$ feet of the same aperture, the Three Telescopes being all of equal excellence, that notwithstanding the central part of the Object-glass of $3\frac{8}{10}$ths diameter was much thicker than that of the Object-glass of $2\frac{7}{10}$ths inches diameter, the superior clearness and defining power of the 5 feet Telescope over its competitors,—the $3\frac{1}{2}$ and the $2\frac{1}{2}$ feet Telescopes,—was much greater than that of the 5 feet itself was with $3\frac{8}{10}$ths aperture, than it was with $2\frac{7}{10}$ths aperture; although with

its whole aperture it defines ε *Bootis*, *Rigel*, and other Double Stars, in the neatest manner, shews the Division in Saturn's Ring extremely well, and, I believe, is as perfect an Instrument as Art can produce :—this observation is a striking proof of the very *great advantage of lenses of long Foci even for Day purposes*.—See pages 284 and 285.

I read the above to Mr. TULLEY, who replied, "That is all right, Sir; I have made many Object-glasses of 2¾ths Aperture and 30 Inches focus — but not one of them was quite so perfect as some I have made of 44 inches focus."

I will here take the liberty to caution those who hereafter may be crazy with the *Dumpy* Mania, that the convenience derived from Achromatic Telescopes being made short, (if beyond a certain proportion,) is greatly more than overbalanced, by the errors produced by the great increase of the aberration of Sphericity arising from the deep curves of the excessively small Eye-glasses we are obliged to employ.

There is much difficulty in getting deep Lenses well worked — and errors arising from any deviation from proper figure, or true centering, are magnified in proportion to the magnifying power of the Lens.

It is almost impossible to find an Eye-glass deeper than the $\frac{1}{16}$th of an Inch focus, that will give a well-defined image of a Star, notwithstanding much

deeper Magnifiers are usable in Microscopes — a Single Eye-glass of half an inch focus, is nearly the shortest that can be conveniently used for viewing Planets.—See *Obs.* on this, in page 64, Chapter V.

Steady Stands are now constructed at a very moderate expense, which make it as easy to use a Telescope of 10 feet, as one of 3 feet in length.

There is a common notion that there is much more trouble in managing a Telescope which is mounted on *Two Stands*, than there is in using an Instrument which is supported on One Stand—the greater trouble in using the former, is only in moving it from one object to another: when once directed to the object, a Double Stand is as easily used as a Single one—and as the Telescope is thereby supported at each end, a Tube of Ten feet in length is as Steady on Two Stands, as a Tube of Two feet is on one Stand — the apparatus of Rack-work for the Two Stands may be so simple, that it need not cost more than One Stand.

About 25 Years ago, I was a Dumpy-fancier myself, and had then the following conversation, with an eminent Optician of great experience :—

*Kit.* How convenient Short Telescopes are! I have bought *a Dumpy**.

* This appellation was first given by Mr. Short, the celebrated Maker of Reflectors, to a Telescope he made for the *Honourable Topham Beauclerc.*

*Opt.* Do you find it perform much better, Sir, than Telescopes of equal aperture that are longer?

*Kit.* No, it certainly does not perform better.

*Opt.* Did you pay less Money for it, then?

*Kit.* No, Sir—a great deal more.

*Opt.* Then I think, Sir, that You have laid out your Money very badly—I guess that you have not got so good a Telescope for £30, as You might have had, with half the trouble to yourself and the Optician, for £20,—for You might have had the choice of 20 Telescopes of the usual length, and what does it signify whether the Tube is 2 or 4 feet long?—a Stand that will carry the one will carry the other; and remember, Sir, that Vision is better, and easier to the Eye in proportion that Magnifying power is produced by Lenses of long foci.—I am presuming, Sir, that the Instrument is employed for purposes where the first consideration is Optical perfection.—However, I ask pardon, Sir, for speaking so plainly, perhaps You purchased your *Dumpy* merely for a Plaything?

*If the apertures of Achromatics, as they are now made, are in regular proportion* to their Focal lengths, the Eye-tube which makes a 2½ feet, of 2 inches aperture, magnify 80, will make a 3½ feet, with an aperture of 2$\frac{7}{10}$ths inches, magnify 120, and a 5 feet, with an aperture of 3$\frac{8}{10}$ths inches, magnify about 180, with the same degree of Illuminating power that the 2½ feet has with the power of 80, that

is, the features of Jupiter and Saturn will be as well illuminated, and will appear as distinctly in the 5 feet with 180, as they do in the 2½ feet with 80.—See *Obs.* in page 73 of the 6th Chapter, on *Reflectors*, after Dr. Smith's Table of the proportions of Newtonian Telescopes; and in page 23, the Introductory Chapter on *Achromatics*, Huygen's Table of the proportions and power of Refractors.

*If Illuminating power is as the Squares of the diameters of the Apertures*—in a 2½ feet Achromatic of 2 inches aperture, it is to a 3½ feet, of $2\frac{7}{10}$ths inches aperture, as 40 is to 72, therefore, a 3½ feet ought to bear a power of 145; and a 5 feet, with an aperture of $3\frac{8}{10}$ths inches, with an Illuminating power of 144, ought to bear a Magnifying power of 290, with as much Light as the 2½ feet has with 80; and would, if the Atmosphere did not prevent it—I have no doubt that the chief cause that they do not, is the intervention of the Atmosphere destroying the *Defining* power of the Instrument.

The pleasant clearness and vividness of the vision with a power of 80, arises from its so little magnifying the Medium which we look through—or by enlarging the Aperture and increasing the Illuminating Power of a Telescope, the higher powers would be as bright, and as distinct as the low power; and a 3 feet Gregorian Reflector, with an aperture of 5 inches, and an Illuminating power of 250, would define objects as distinctly, when made to magnify 250 times, as a 1 foot Gregorian, with an

aperture of $2\frac{6}{10}$ths inches, and an Illuminating power of 52, does when it is made to magnify 52 times—but about $\frac{2}{3}$ds of 250, or about 160, approximates to the maximum which a Gregorian of 5 inches aperture will magnify for observing Planets—with a higher power, their features appear less distinctly, except when they are near to the Meridian, and the Air is uncommonly clear, and the Instrument exquisitely perfect.

*A* 30 *Inch Achromatic*, with an aperture of 2 inches, and of which I have called the Illuminating power 40, will bear a Magnifying power of double that—*i. e.* 80 for either Jupiter or Saturn.

*A* $3\frac{1}{2}$ *Feet*, of $2\frac{7}{10}$ths inches aperture, and Illuminating power of 72, will bear a Magnifying power of double that, 144, but is pleasanter with 120.

But *a* 5 *Feet*, whose aperture is $3\frac{8}{10}$ths inches, and Illuminating power is 144, will not bear a Magnifying power of double that, 288—but $\frac{2}{3}$ds of that power, 190, or indeed 160, is enough for the Planet Saturn. I have not seen any Telescope which would bear a higher power than a little more than 200 times for observing *Saturn*.—See Chapter XIX. on *Saturn*.

The Visibility of the Belts of *Jupiter*, and the Black Division in the Ring of *Saturn*, the Magnifying powers of the Telescopes being the same, is in proportion to the Illuminating and Defining powers of the Telescope,—or, in honest plain English, as that is large, and is perfect.

When I first began to play with Telescopes, in the

Year 1796, I purchased a $3\frac{1}{2}$ feet Achromatic with a double Object-glass of $2\frac{7}{10}$ths inches aperture, but hearing *the 46 Inch Telescope, with a Treble Object-glass of* $3\frac{6}{10}$*ths inches aperture*, very highly spoken of, I supposed that it was quite impossible that I could be quite happy, till I obtained a Telescope of that kind; and as a man who wishes to make good work, does wisely to provide himself with good tools, as soon as I could, I purchased a very good 46 Inch—but on comparing it with the former glass of $2\frac{7}{10}$ths inches aperture, with equal powers of 130, I was disappointed to find, that all the difference which my inexperienced Eye could perceive, was that *Jupiter* appeared a little whiter and brighter in the larger than it did in the smaller glass.—If I had observed the Immersions or Emersions of *the Moons of Jupiter*, I should have soon seen that the Immersions were visible later—and that the Division in Saturn's Ring was much plainer in the larger Aperture than it was in the smaller.

## MR. TULLEY'S LETTER.

"Territ's Court, Islington,
Feb. 16, 1824.

"DEAR SIR,

"The subject of our conversation yesterday, *The Illuminating power of Telescopes* of various constructions, has often occupied my attention.

"At the same time that I finished the *Achromatic* Telescope, which I made for Mr. JAMES SOUTH, F.R.S.

of 7 feet focus, with a Double Object-glass of 5 inches aperture, I completed a *Newtonian* Reflector, also of 7 feet focus and $6\frac{8}{10}$ths clear aperture, and frequently compared the Instruments at various objects; myself, and my son, observed the Immersions of Jupiter's Satellites with them, and could see the Satellite just as well and as long with the one as with the other Telescope. From this, and from various other trials of them, I am induced to say, that when the Magnifying powers were equal, we considered the Illuminating Powers of the two Instruments to be equal also.

" I have several times very carefully compared a *Newtonian* Reflector with a *Gregorian*, and when the aperture of the former was as $6\frac{3}{10}$ths inches to $6\frac{8}{10}$ths of the latter, that is, as 39 to 46, with the same Magnifying powers, their light appeared about the same, but I think that *the Newtonian* was the most Effective Instrument.

" I may be allowed to observe, that I believe that the 7 feet Achromatic above mentioned, is the only Achromatic Telescope of that focus which has been made in this country of 5 inches aperture,—the Magnifying powers were from 100 to about 500 times, and with the latter Power, I saw, for the first time, η *Coronæ Borealis* distinctly Double,—and, with a Power of 350, α *Lyræ* was shewn Double.

" I am, Sir, your very obedient servant,

" CHAS. TULLEY."

" To Dr. KITCHINER."

The degree of *Light reflected by a Reflecting Telescope,* and the perfectness of its vision, may be imagined, by considering that the Telescope with which Dr. HERSCHEL made his first Catalogue of Double Stars, and with which he discovered them, (see page 249 of vol. lxxiii. of the *Phil. Trans.*) was of only 4½ inches aperture, 7 feet focus, and power 222, with which, Dr. H. informs us that the vacancy between the two Stars of *Castor* appeared to be a little more than 1 diameter of the Larger Star; and that when the aperture of his 7 feet Newtonian was contracted to 3½ inches, with 460, the vacancy between the Two Stars of ε *Bootis* was ½ a diameter of the Smaller Star.—See Chapter XX on *Double Stars;* and the *Phil. Trans.* vol. xcv. p. 42—and see Dr. H.'s diagram of *Castor,* in the Frontispiece to this work.

Length of focus is not so needful in *Gregorian* Telescopes; I have one made by WATSON, of 12 inches focus and 4 inches Aperture, (see page 117)—which, with a power of 260, divorces the Two Stars of ε *Bootis* very distinctly—I was quite as much surprised the first time that I saw this, as the Reader can possibly be:—this Instrument defines *Castor* as neatly as I have delineated it in the diagram in the Frontispiece; the stars appear smaller and sharper defined than I have seen them in any Achromatic.

COMPARATIVE LENGTHS, APERTURES,

ACHROMATIC REFRACTORS

| Length and name they are called by. | Diameter of Aperture. | Illuminating power. | Price. | |
|---|---|---|---|---|
| *Feet.* | *Inch. Tenths.* | | *L. s.* | |
| 2 | 1 6 | 25 | 4 4 | not equal to a |
| 2½ | 2 | 40 | 12 12 | —— |
| 3½ | 2 7 | 72 | 21 0 to 42 0 | —— |
| 5 | 3 8 | 144 | 105 0 to 150 0 | —— |
| 7 | 5 | 250 | 250 0 | —— |
| 7 | 6 | 360 | 360 0 | —— |

* *In Long Gregorian Telescopes* it is impossible to get a Mag-
shew the whole of the Moon — or for the purpose of a Day Tele-
a 9 inch metal of 3 feet focus — and mounted on a portable
man, and yet sufficiently steady, (see page 120.) My 9 inch
inches focus.—See the evidence of the defining power of a Gre-
the last paragraph of the *preceding page* (297); and on the propor-

## ILLUMINATING POWERS, AND PRICES, OF

## AND GREGORIAN REFLECTORS.

| Length and name they are known by | Diameter of Aperture. | Illuminating power. | Price. |
|---|---|---|---|
| *Feet.* | *Inch. Tenths.* | | *L. s.* |
| 1 | 2 5 | 62 | 7 7 |
| 1½ | 3 | 90 | 12 12 |
| 2 | 4 5 | 202 | 20 0 |
| 3 | 5 5 | 302 | 50 0 with rack- |
| { 4 | 7 | 490 | 105 0 [work. |
| { 7 Newtonian. | 7 | 490 | 126 0 |
| { 5 Gregorian*. | 9 | 810 | 200 0 |
| { 10 Newtonian. | 10 | 1000 | 315 0 |

nifying power sufficiently low, and with sufficiently large field, to
scope—however, by paying a proportionate price you may have
Stand, which may be easily made so light as to be carried by one
aperture Gregorian, which was made by Mr. WATSON, is only 27
gorian whose focal length is only 3 diameters of its Aperture, in
tions of Focal Lengths to Apertures, read pages 86 and 87.

When the Telescopes, which are placed opposite to each other in the preceding Table, are equally perfect, and are charged with equal magnifying powers, if proper care be bestowed upon the Reflectors, and their *Defining** power is equal to that of the Gregorian mentioned at page 297 — and a Telescope-fancier has only himself to blame if he purchases an instrument without giving it a proper trial—(read Chapters XII. and XIII.)—*the Reflectors* will be superior, as the pencil of Rays reflected by them, is more than double the diameter of that transmitted by the *Achromatics:*—the easiest way to obtain fine Telescopes,—fine Stockings,—fine Stewpans, and all other Fine Things, I have shewn in page 42.

The preceding Table is not a mere Theoretic affair, but is the result of comparisons of Object-glasses and Specula, with equal *Magnifying* powers, and whose *Defining* powers were equal.

*It is to no purpose that the Telescopes are of equal size, if the* MAGNIFYING *and the* DEFINING *powers are not equal.*

*First,* ascertain the Magnifying powers by *Ramsden's Dynameter,* (see page 238.)

*Secondly,* try their Defining powers by the various tests pointed out for that purpose, in the Chapters XII. and XVIII. on *Choosing Telescopes.*

* See the account of the performance of a 4 inch Aperture Gregorian, in the last paragraph of page 297, in page 117, and in the Observations on Double Stars—at the end of this work.

*Thirdly*, try both the Telescopes at the same Object, with the same Magnifying powers, and, as nearly as can be, at the same moment, for,—THE EYE *has a worse Memory than either of our other Senses.*

I might almost as well not have put any Achromatic as being on a par with a Reflector of 7 inches aperture, because, no Achromatic Object-glass can transmit so much light as a fine and perfect 7 inch Speculum reflects, unless it be full 5 inches in diameter, and not less than 7, and I should prefer it of 10, feet focal length:—where are such Achromatics to be obtained?

Moreover, a Gregorian of 3 or 4, or a Newtonian of 7 feet focus, and an Aperture of 7 inches, may be purchased for half the price charged for an Achromatic of 5 inches Aperture.

I have not seen a fine Achromatic Object-Glass of more than $3\frac{8}{10}$ths inches in diameter.—See Mr. P. Dollond's Letter to Mr. Short, in the *Phil. Trans.* for 1765,—and page 16 of this work.

On the calculation that the pencil of Rays from a Reflector must be twice the diameter of that from an Achromatic; a Reflector of 7 inches Aperture will have more than one-third more light than an Achromatic of $3\frac{8}{10}$ths Aperture.

## DR. HERSCHEL ON MAGNIFYING POWER.

"THE question '*How much a Telescope magnifies?*' admits of various answers. To resolve it properly,

we ought in all circumstances to consider how far the Magnifying power of a Telescope is supported by an adequate quantity of Light; as without it the highest power and distinctness cannot be *efficient*. The question, therefore, ought to be limited to an inquiry into the extent of what may be called the *effective* magnifying power? It will, however, be found, that even then, the quantity of this power cannot be positively assigned. For if a card containing engraved letters of a certain size be put up at a great distance, the effective power of a telescope directed to it, will be that wherewith we can read these Letters with the greatest facility; but if either the size of the letters, or their distance from the telescope, be changed, the quantity of this power will no longer remain the same. An obvious consequence of this consideration is, that the effective power of telescopes has a considerable range of extent, and can only be assigned when the object to be viewed is given."—Dr. Herschel, in vol. cv. of *Phil. Trans.* p. 294.

" It will, however, be proper, to point out from experience some of the advantages that may be taken, if not to increase, at least not to obstruct, the penetrating power, by the full effect of which the magnifying power is to be supported.

" The first precaution I ought to give is, that in these delicate observations, *no Double Eye-Glass* should be used, as it cannot be prudent to permit

the waste of light at four surfaces, when two will collect the rays to their proper focus. The hole through which they pass in coming to the eye, should be much larger than the diameter of the optic pencils, and considerably nearer the glass than their focus; for *the Eye ought on no account to come into contact with the Eye-piece;* and a little practice will soon enable the observer to keep his eye to the required situation.

"It is hardly necessary to add, that no hand should touch the Eye-piece." (p. 295.)

DR. HERSCHEL ON THE POWER OF PENETRATING INTO SPACE BY TELESCOPES; WITH A COMPARATIVE DETERMINATION OF THE EXTENT OF THAT POWER IN NATURAL VISION, AND IN TELESCOPES OF VARIOUS SIZES AND CONSTRUCTIONS; ILLUSTRATED BY SELECT OBSERVATIONS.

[*Phil. Trans.* vol. xc, p. 49.]

"IT will not be difficult to shew that the power of Penetrating into space by Telescopes, is very different from Magnifying power; and that in the construction of Instruments, these two powers ought to be considered separately." (p. 49.)

"*The aperture of the pupil of the Eye* in different persons, differs considerably. Its changes are not easily to be ascertained, but we shall not be much

out, in stating its variations to be chiefly between one and two tenths of an inch. Perhaps this may be supposed underrated; for the powers of vision in a room completely darkened will exert themselves in a very extraordinary manner.

"In some experiments on light made at Bath, in the year 1780, I have often remarked, that after staying some time in a room fitted up for these experiments, where on entering I could not perceive any one object, I was no longer at a loss in half an hour's time, to find every thing I wanted. It is, however, probable, that the opening of the Iris is not the only cause of seeing better after remaining long in the dark, but that the tranquillity of the retina, which is not disturbed by foreign objects of vision, may render it fit to receive impressions such as otherwise would have been too faint to be perceived. This seems to be supported by telescopic vision; for it has often happened to me in a fine winter's evening, when, at midnight, and in the absence of the Moon, I have taken sweeps of the Heavens, of four, five, or six hours' duration, that the sensibility of the Eye, in consequence of the exclusion of light from surrounding objects, by means of *a Black Hood*, which I wear upon those occasions, has been very great; and it is evident that the opening of the Iris would have been of no service in these cases, on account of the diameter of the optic pencil, which, in the 20 feet telescope at the

time of sweeping, was no more than the .12 of an inch.

"The effect of this increased sensibility was such, that if a star of the 3d magnitude came towards the field of view, I found it necessary to withdraw the eye before its entrance, in order not to injure the delicacy of vision acquired by long continuance in the dark.

"The transit of large stars, unless where none of the 6th or 7th magnitude could be had, have generally been declined in my sweeps, even with the 20 feet Telescope.

"I remember that after a considerable sweep with the 40 feet instrument, the appearance of *Sirius* announced itself at a great distance, like the dawn of morning, and came on by degrees, increasing in brightness, till this brilliant star at last entered the field of the telescope with all the splendour of the rising sun, and forced me to take the eye from that beautiful sight.

"Such striking effects are a sufficient proof of the great sensibility of the eye, acquired by keeping it from the light." (p. 54.)

"On taking notice, in the beginning of sweeps, of the time that passed, I found that the eye, coming from the light, required near twenty minutes before it could be sufficiently reposed to admit a view of very delicate objects in the telescope; and that the observation of a transit of a star of the 2d or 3d

magnitude, would disorder the eye again, so as to require the same time for the re-establishment of its tranquillity."

"The difficulty of ascertaining *the greatest opening of the eye,* arises from the impossibility of measuring it at the time of its extreme dilatation, which can only happen when every thing is completely dark; but we have no difficulty to determine the quantity of light admitted through a telescope, which must depend upon the diameter of the Object-glass or mirror." (p. 55.)

"We now proceed to *the Powers of Telescopes Penetrating into Space.* In order to come to some determination on this subject, I made many experiments with plain mirrors. The method I pursued was that proposed by Mr. Bouguer, in his *Traité d'Optique,* p. 16, fig. 3; but I brought the mirror, during the trial, as close to the line connecting the two objects as possible, in order to render the reflected rays nearly perpendicular.

"The result was, that out of 100,000 incident rays 67,262 were returned, and therefore, if a double reflection takes place, only 45,242 will be returned.

"Before this light can reach the Eye, it will suffer some loss in passing through the Eye-Glass, and the amount of this, I ascertained, by taking a highly polished plain glass of nearly the usual thickness of optical glasses of small focal lengths. Then,

by the method of the same author (p. 21, fig. 5) I found that out of 100,000 incident rays, 94,825 were transmitted through the glass. Hence, if *two lenses* be used 89,918, and with *three lenses* 85,265 will be transmitted to the eye. Then, by compounding, we shall have in a Telescope of my construction with one reflection, 63,796 rays out of 100,000 rays come to the Eye.

" In the Newtonian form, with *a single Eye-lens*, 42,901, and with *a double Eye-glass*, 40,681 will remain for vision.

" There must always remain a considerable uncertainty in the quantities here assigned; as a new polished mirror, or one in high preservation, will give more light than another that has not those advantages. The quality * of metal will also make some difference." (p. 65.)

" In the *Newtonian* and other constructions, where *two specula* are used, there will also be some loss of light, on account of the interposition of the small *speculum*.

" *I suppose two-tenths of an Inch as being perhaps the general opening of the Iris in Star-light nights,* when the eye has been some moderate time in the dark." (p. 66.)

* Messrs. Tulley and Watson have assured me, that the Specific Gravity of the Metal makes a great difference in its reflective power, and that Specula reflect light in proportion to their Densities.

"In the year 1776, when I had erected a telescope of 20 feet focal length, of the Newtonian construction, one of its effects by trial was, that when towards evening, on account of darkness, the natural eye could not penetrate far into space, the telescope possessed that power sufficiently to shew, by the dial of a distant church steeple, what o'clock it was, notwithstanding the naked eye could no longer see the steeple itself.

"Here I only speak of the penetrating power; for, though it might require magnifying power to see the figures on the dial, it could require none to see the steeple. Now the aperture of the telescope being 12 inches, and the construction of the Newtonian form, its penetrating power, when calculated according to the given formula, will be $\sqrt{\underline{429 \times \overline{120}^2 - \overline{15}^5}} = 38.99$, $A$, $b$, $a$, being all expressed in tenths of an inch.

"I have given the figures, in all the following equations of the calculated penetrating powers, in order to shew the constructions of my instruments to those who may wish to be acquainted with them." (p. 67.)

"The distinction between magnifying power and a power of penetrating into space, could not but be felt long ago, though its theory has not been inquired into. This undoubtedly gave rise to the invention of those very useful short telescopes called NIGHT-

GLASSES. When the darkness of the evening curtails the natural penetrating power, they come in very seasonably to the relief of mariners that are on the look-out for objects which it is their interest to discover.

" *Night-glasses*, such as they are now generally made, will have a power of penetrating six or 7 times farther into space than the natural eye. For, by the construction of the double Eye-glass, these telescopes will magnify 7 or 8 times, and the Object-glass being $2\frac{1}{2}$ inches in diameter, the breadth of the optic pencil will be $3\frac{1}{8}$th or $3\frac{1}{7}$th of an inch. As this cannot enter the eye, on a supposition of an opening of the Iris of 2 tenths, we are obliged to increase the value of $a$, in order to make the telescope have its proper effect.

" Now, whether nature will admit of such an enlargement becomes an object of experiment; but, at all events, $a$ cannot be assumed less than $\frac{A}{m}$. Then, if $x$ be taken as has been determined for three refractions, we shall have $\frac{\sqrt{853 \times 25^2}}{a} = 6.46$ or $7.39$." (p. 69.)

" The 20 feet reflector having been changed from the Newtonian form to my present one, (i. e. the *Front View*,)* I had a very striking instance of the

* " The *Front view* is a method of using the reflecting telescope different from the Newtonian, Gregorian, and Cassegrain

great advantage of the increased penetrating power, in the discovery of the Gregorian satellites.

"The improvement, by laying aside the small mirror, was from 61 to 75; and whereas the former was not sufficient to reach these faint objects, the latter shewed them perfectly well." (p. 75.)

"Among other instances of the superior effects of penetration into space, I should mention the discovery of an additional *Sixth satellite of Saturn,* on the 28th of August, 1789, and of a *Seventh* on the 11th of September, in the same year, which were first pointed

forms. It consists in looking with the eye-glass, placed a little out of the axis, directly in at the front, without the interposition of a small speculum; and has the capital advantage of giving us almost *double* * the light of the former constructions. In the year 1776 I tried it for the first time with a 10 feet reflector, and in 1784 again with a 20 feet one; but the success not immediately answering my expectations, it was too hastily laid aside. By a more careful repetition of the same experiment I find now, that several other considerable advantages, added to the brilliant light before mentioned, make it so valuable a construction, that a judicious observer may avail himself of it, at least in all cases where light is more particularly wanted; and from the experience of thirty sweeps, which I have already made with it, I may venture to announce it to be a very convenient and pleasant, as well as useful, way of observing. With regard to the position of objects, it differs from other constructions, by inverting the north and south, but not the preceding and following."—Dr. Herschel, in *Phil. Trans.* for 1786, vol. lxxvi. p. 499.

* In the text Dr. H. calculates it at *one-fifth* more—as 75 to 61.—(*See the 4th line of this page.*)—W. K.

out by the instrument (40 feet). It is true that both Satellites* are within the reach of the 20 feet telescope; but it should be remembered that when an object is once discovered by a superior power, an inferior one will suffice to see it afterwards.

"I need not add, that neither the 7 nor 10 feet telescopes will reach them; their powers, 20 and 29, are not sufficient to penetrate to such distant objects, when the brightness of them is not more than that of these satellites. It is also evident, that the failure in these latter instruments, arises not from want of magnifying power; as either of them has much more than sufficient for the purpose." (p. 77.)

"From my long experience in these matters, I am led to apprehend that the highest power of magnifying may possibly not exceed the reach of a 20 or 25 feet telescope; or may even lie in a less compass than either.

"However, *in beautiful Nights,* when the outsides of our telescopes are dropping with moisture discharged from the atmosphere, there are now and then favourable hours in which it is hardly possible to put a limit to magnifying power.

"But such valuable opportunities are extremely

* I have twice seen both these Satellites perfectly plainly, in a 12 feet Achromatic of 7 inches Aperture, with a Magnifying power of 150, made by Mr. TULLEY.—See a particular account of this observation, in Chapter XIX. of this work.—W. K.

scarce, and with large instruments it will always be lost labour to observe at other times." (p. 81.)

"From what has been said before, we may conclude, that *objects are viewed in their greatest perfection*, when, in penetrating space, the magnifying power is so low as only to be sufficient to shew the object well; and when, in magnifying objects by way of examining them minutely, the space-penetrating power is no higher than what will suffice for the purpose: for, in the use of either power, the injudicious charge of the other will prove hurtful to perfect vision."

## CHAPTER XVIII.

### HOW TO CHOOSE, AND HOW TO USE TELESCOPES FOR CELESTIAL PURPOSES.

To Compare Instruments, and to ascertain their peculiar powers—be not satisfied with less than Three Nights' trial, and try a variety of Objects—*Double Stars—Planets—Day-Objects*, &c.

It is of the first importance, that the Reader should be fully aware, that such is the ever-changing and vibrating state of the Atmosphere of this Country, that some Evenings which appear to be extremely fine, and the Stars are brilliant and dazzling to the naked Eye, are quite unfit for observation with Telescopes; and the best Glasses shew Stars like Darts, and Planets not with a sharply defined disk, but tremulous and hazy, and the Division in the Ring of Saturn is hardly visible.

February the 3d, 1825, was such a Night as this. My best Telescope acted so imperfectly, that I thought it had been put out of adjustment, till on comparing it with a very perfect 30 Inch Achromatic, I discovered that the Atmosphere was extremely unfavourable for Observation: it generally is when the wind is in the East.

In the morning of the 4th of February, there was a fall of Snow, and at intervals during the day till 6 in the Evening—at ½ past 9, the air was favourable for observation, and I saw the Division in Saturn's Ring very distinctly—it is impossible to guess whether a Night is well adapted for Celestial observations till you try; and Instruments are often condemned, when the Atmosphere only is in fault.

"For if there be any vapours moving and undulating in the atmosphere, which often happens, though the night appears clear to the naked eye, these will entirely destroy the distinctness of the appearance: and it often happens that the air in this respect, at least here with us at Kew, will so suddenly and so totally alter, that the object will appear very distinct and very confused afterwards in 3 or 4 seconds of time; and the air is sometimes so very variable, that objects will appear instantaneously to change from being very clear to be confused, and then to be clear again. It will, therefore, be proper to accustom one's self to the fluctuating appearances of some land-objects, seen in the day time through the reflector; lest the undulating appearances of the planets in the night may deceive one, and incline one to think this instrument does not succeed so well as it is certain it will in a pure undisturbed Air."—Dr. SMITH's *Optics*, 4to. vol. ii. p. 366.

"I have had recourse to my Journals, to find *how*

*many Favourable Hours we may Annually hope for in this Climate.*

"It is to be noticed, that the Nights must be very clear—the Moon absent—no Twilight—no Haziness—no violent Wind—and no sudden change of Temperature;—and it appears that *a Year which will afford* 90, *or at most* 100 *Hours, is to be called a very productive one*"!!!—Sir W. H. in p. 84 of vol. xc. of the *Phil. Trans.*

This calculation of Sir William H. may surprise the Novice, until he understands that a Planet or Star is only in a situation for high Magnifying power, about half the time that it is above the Horizon—*i. e.* it must be within Three, and for the highest Magnifiers within One, Hour of the Meridian.

However, this scarcity of Clear Nights is not to be lamented quite so much as the Reader may at first imagine—the strongest sight will be fatigued, nay, will soon be impaired, if employed too often on such Eye-straining business.

*To ascertain to a certainty, whether the Atmosphere or the instrument is in fault;* have a 30 Inch Achromatic Telescope, of proved perfectness; and before you try a New Telescope, see how that acts whose performance you are acquainted with.—I recommend an Achromatic, because they are more uniform in their action than Reflectors.—See Sir Wm. Herschel's Paper, on the *Causes which prevent*

*Mirrors shewing Objects distinctly*—and the Chapter on *Double Stars*.

I have never seen the face of *Saturn* more distinctly than in a Night when the Air has been so hazy, that with my naked Eye, I could hardly discern a Star of less than the third magnitude.

The degree of the transparency of the Air is varying almost every minute, so that even in the course of the same quarter of an hour, Planets and Stars will appear distinctly defined, and "*vice versá*."

*To make any thing like an accurate comparison of Telescopes*, they must be tried, not only at the same Place, but as nearly as possible at the same Minute — and if the Instruments are of the same Length and construction, if possible, with the same Eye-tube.

See that the Eye-tubes are glassed with the same kind of Glass, and that they are of the same Magnifying power, or the comparison will be in vain.

A difference of 5 or 10 times in the Magnifying power, will sometimes, on some Objects, give quite a different character to a Telescope — thus Object-Glasses of an inch or two longer focus, will give different vision with the same Eye-piece. — See Mr. TULLEY's *Letter*, at p. 165.

The Colour, the Density, and the Condition, of the Speculum of a Reflecting Telescope, is as important as the colour of the Glasses, of an Achromatic.

See that the Eye-glasses are free from defects, and are perfectly *clean;* if they are not, wipe them carefully with a piece of quite new and soft Lamb's-skin leather;—in replacing them, take care not to touch their surfaces with your fingers, but take hold of the edges only, and screw them into the same places you took them out of.

*The Defects of Glass* are either from Veins—Specks—Scratches—Colour—or false Figure.

To discover *Veins* in an Eye-Glass or an Object-Glass, place a Candle about 5 or 6 yards from you; then look through the Glass, move it from your Eye till you find it full of Light, and you will then clearly see every vein, &c. in it, which renders Vision imperfect by distorting the Objects.

*Specks* or *Scratches* are not so mischievous as *Veins,* for they do not distort the object, but only intercept part of the Light;—however, such defective Glasses should not be used.

Whatever difference there may be in the dimensions of the Instruments, if we wish to be acquainted with their respective qualities, they should be first charged with exactly the same Magnifying Power (see p. 238); if the Telescopes are for Celestial use, this should not be less than 100—if for Terrestrial, not less than 50. After this, you may proceed to try those powers, with which each Instrument acts, most perfectly; for ascertaining of which,

we have already given directions in Chapters XII., XIII., and XIV.

You cannot judge accurately of the excellence of any Telescope, by observing any object which you are not acquainted with.—" Every Eye reads best out of its own Book"—and Opticians have assured me, that to pronounce positively on the quality of an Instrument, they must try it at their own Marks.

The Dial-plate of a Watch, placed about 100 feet from the Telescope, is *an Excellent Test* of the distinctness and Achromaticalness of a Glass, especially when the Sun shines strongly upon it—so is a Weathercock, or any object in the Day, with a bright light behind it, and the Moon, and best of all the Planet Jupiter, when near to the Meridian.

These are severe tests of the Achromaticalness of an Instrument, and there are very few which will not shew some colour about the edges of all these objects; and in proportion that they do so, they are imperfect for Astronomical purposes.

Those Achromatic Telescopes, which from their being a little *over-corrected*, that is, when the focal length of the *Convex* is formed a little too long for the *Concave*—and the purple rays rather predominate, are considered to be the most brilliant and distinct in the Day time, are proportionately inferior for Celestial purposes.

Dr. Smith, in his Remarks on Optics, observes, in

his 2d vol. p. 80:—"Of several Telescopes of the same length, same Aperture, and same Magnifying power, that is the best with which you can read a given print at the greatest distance."

This is a good proof of the power of a Day Telescope, but a very inadequate proof of its fitness for Celestial purposes.—See Chapters on *Saturn* and on *Double Stars*.

"Magnifying very minute objects, and particularly reading at a distance, have been generally considered as the surest tests of the goodness of a Telescope;—and, indeed, when the page is placed at a great distance, so that the Letters subtend but a very small angle at the Eye; if then they appear with great precision and sharpness, it is most probable that the Instrument is a good one. But yet we are sometimes apt to be deceived by this method; nor is it always possible to determine on the different merits of 2 Instruments of equal power, by this mode of examination; for when the Letters are removed to the utmost extent of the powers of the 2 Instruments, the Eye is apt to be prejudiced by the Imagination. If 2 or 3 Words can be here and there made out, all the rest are guessed at by the sense; insomuch that an observer, zealous for the honour of his Instrument, is very apt to deceive himself in spite of his intentions.

"The surest Test is by Figures. In order to examine my Reflecting Telescopes, I made on a

piece of copper, and on a black ground, 6 lines, consisting of about 12 pieces of gold figures, and each line of figures differing in magnitude from the smallest that could be distinctly made, to those of about $\frac{2}{10}$ths of an inch long; besides, the figures in the several lines were differently disposed, and the sum of each line also differed. It is evident, that by this method all guess is precluded; and that of 2 instruments, of the same powers, that which can make out the least order of figures, which will be known by the sum, is the best Telescope. Such a plate I caused to be fixed up for experiments against the top of a Steeple, about 300 Yards north of my house; and it will serve to give some idea of the distinctness with which very small figures could be made out at that distance, by saying, that in a clear state of the air, and with the sun behind me, with a Telescope of 18 inches focal length, I have seen the Legs of a small Fly, and the shadows of them, with great precision and exactness."—Mr. J. MUDGE *on Reflecting Telescopes, from the Phil. Trans. for* 1777.

The Atmosphere appears most transparent when there is least wind—vision seems better, because the Telescope is still.

*If your Telescope stands in an* OBSERVATORY which has a moveable Dome, or sliding shutters in the Roof, these Apertures should be opened half an hour before you put out your Glass—for if the tem-

perature of the external air, and the air in the room, be not the same, in the degree in which they differ, will your Instrument, especially a Reflecting Telescope, in a wooden Tube, perform imperfectly. The only comfort of such an Observatory is, that it shields you from Currents of Wind.

Nor will a large Reflector perform properly for some time after it has had a violent shake, therefore, the *Stands of large Reflectors* should be upon easy-moving Castors, like those applied by Sir Wm. H.

*The best Roof for an Observatory* to use a Telescope in, is that which can be thrown back entirely on each side—and is not above 6 feet from the floor, so that the Observer can see all around to the very edge of the Horizon.

"It is manifest, that Observations made in the Open Air promise the greatest degree of consistency with each other, and the best elements for a theory and law of refractions; but as this method, particularly in our Northern Climates, cannot be pursued with safety, either to the Astronomer or his apparatus, we can only endeavour to approximate to this perfection, by making our buildings as open to the Air as may be consistent with their particular structure, and the health and convenience of the observer.

"The Meridian Apertures for the Transit Instrument and Circle, are 6 feet wide; which is a breadth considerably greater than I have heard of in any

Observatory. These, or a part of them, should be left open until the temperature within, and that abroad, are found to agree entirely, or as nearly as can be effected: through these and the windows, there is a free admission of air—and that the temperature within may at all times be more nearly equal to that of the external air; there are semicircular air-holes in the walls, grated and covered with thin wide canvass, which are always left open to the air, except in wet or damp weather, when they are closed with shutters within."—Dr. USHER's *Account of the Observatory of Trinity College, Dublin, in pages* 5 *and* 17 *of the* 1*st vol. of the Transactions of the Royal Irish Academy*, 4*to*, 1787.

" (40.)—Oct. 10, 1780, 6h. 30m. Having just brought out my Telescope, it will not act well.

" 6h. 45m. The Tube and Specula are now in order, and perform very well.

" (41.)—Jan. 11, 1782. To all appearance the Morning was very fine, but still the Telescope, when first brought out, would not act well. After *half an hour's* exposure, it performed better."—Dr. HERSCHEL, in vol. xciii. of *Phil. Trans.* p. 217, and following.

" *The Observer**, as well as the Instrument, must

* Then a poor Star-gazer, on a cold frosty night, must be *frozen* before he can see,—this may certainly qualify him for observations on the other side of the *Styx* ! ! !

have been long enough out in the Open Air to acquire the same Temperature*. In very cold weather, an hour, at least, will be required; but in a moderate Temperature, half an hour will be sufficient."—Dr. HERSCHEL's *Obs.* on 19 *h* Draconis, near Fl. 20—in his *First Catalogue of Double Stars*, in vol. lxxii. of the *Phil. Trans.*

I find the following observation in my own Journal:—

1808, May 1. CARY's 7 feet Newtonian Reflector, 7 Inches Aperture—*Saturn* with 240, very beautiful, the division in the Ring, and the Belts, seen very distinctly,—the Telescope in the Observatory—as good after the first *half-hour*, as after the Windows and Door had been open for two hours.

To avoid Currents of Air passing before the Glass, whenever the Weather will permit, let the Telescope be taken out of Doors—it will seldom do its utmost, unless it be placed on the Ground, in the Open Air, at least a quarter of an hour before you use it, and the object of Observation is near to the Meridian.

Objects are not only much better seen with any given Eye-tube, in proportion that they are near to the MERIDIAN, but we may use a higher Mag-

* According to SMEATON, "Glass expands $\frac{1}{1200}$th in length for 800° of temperature, consequently it expands $\frac{1}{400}$th in bulk"—and "Speculum Metal expands .001933 in Length—and .005811 in Bulk."—BUCHANAN *on Fuel*, 8vo, 1810, pp. 35 and 39.

nifier.—See my *Obs. on Saturn*, which, when close to the Meridian, was as sharp with 190, as when Two hours from it it was with 160, or Four hours from it with 130.

If the Instrument has been kept in a room, the temperature of which is warmer than the open air, take off the cover of the Object-end, and take out the Eye-piece, and let the air pass through the Tube for 10, or 20, or more minutes.

For the same space of time, the Eye must avoid all stimulating and bright objects; so that the Pupil may be in its most expanded and sensitive state.

The larger the Telescope, the longer time it will take to acquire the Temperature, especially if it has *a Wooden Tube*, and the Large Speculum is above 5 inches in diameter.

My Great Dumpy Gregorian, whose Large Metal is $9\frac{8}{10}$ths inches in diameter, is seldom in good temper till it has been exposed to the external air for at least Half an Hour.

"A 40 feet telescope should only be used for examining objects that other instruments will not reach. To look through a larger Telescope than required is loss of time, which, in a fine night, an astronomer has not to spare; but it ought to be known that the opportunities of using the 40 feet reflector, are rendered very scarce by two material circumstances. The first is the changeable temperature of the atmo-

sphere, by which the mirror is often covered with the condensation of vapour upon its surface, which renders it useless for many hours; and in cold weather, by freezing upon it for the whole night, and even for weeks together; for the ice cannot be safely taken off till a general thaw removes it. The next is, that, with all imaginable care, the polish of a mirror exposed, like that in the 40 feet telescope, though well covered up, will only preserve its required lustre and delicacy about two years."—See *Phil. Trans.* vol. civ. p. 275.

"The *large Speculum* is 49½ inches in diameter, but on the rim is an offset ¾ths of an inch broad, and 1 inch deep, which reduces the concave face of it to a diameter of 48 inches of polished surface."

When the Eye is properly prepared, the sensibility of our Sight is increased very considerably; and when the Division in Saturn's Ring, and difficult and delicate Double Stars, are the objects of examination, Sir W. H. cautions us, that "it is in vain to look for them, unless every circumstance be favourable;" and such preparation of both the Eye and the Instrument are indispensable.

I have found it very necessary, to occasionally rest the Eye for a few minutes: that it may recover its irritability, which is soon exhausted when stimulated by an intensely bright object.

When a Light is necessary, to find an Eye-piece, or rectify the Instrument, *to prevent the adjustment*

*of the Eye being disturbed*, use a small Lantern, which gives a faint Light only on one side.

OBSERVATIONS AND EXPERIMENTS RELATING TO THE CAUSES WHICH OFTEN AFFECT MIRRORS, SO AS TO PREVENT THEIR SHEWING OBJECTS DISTINCTLY. (From Dr. HERSCHEL's Paper in p. 217, &c. of vol. xciii. of the *Phil. Trans.*)

"It is well known to astronomers, that telescopes will act very differently at different times. The cause of the many disappointments they may have met with in their observations, is, however, not so well understood.

"Sometimes we have seen the failure ascribed to certain tremours, as belonging to Specula, and remedies have been pointed out for preventing them. Not unfrequently, again, the telescope itself has been condemned; or, if its goodness could not admit of a doubt, the weather in general has been declared bad, though possibly it might be as proper for distinct vision as any we can expect in this changeable climate.

"The experience acquired by many years of observation, will, however, I believe, enable me now to assign the principal cause of the disappointments to which we are so often exposed.

"Unwilling to hazard any opinion that is not pro-

perly supported by facts, I shall have recourse to a collection of occasional observations. They have been made with specula of undoubted goodness, so that every cause which impeded their proper action must be looked upon as extrinsic.

" I shall arrange these observations under different heads, that, when they have been related, there may remain no difficulty to draw a few general conclusions from them, which will be found to throw a considerable light upon our subject.

" MOISTURE IN THE AIR.

" (1.)—October 5, 1781. I see double stars, with 460, completely well. The air is very damp, which proves that damp air is no enemy to good vision.

" (4.)—Dec. 28, 1782. 17h. 30m. The water condensing on my tube, keeps running down, yet I have seen very well all night. I was obliged to wipe the Object-glass of my finder almost continually. The specula, however, are not in the least affected with the damp. The ground was so wet, that in the morning several people believed there had been much rain in the night, and were surprised when I assured them there had not been a drop." (p. 219.)

" FOGS.

" (9.)—Oct. 30, 1779. It grows very foggy, and the moon is surrounded with strong nebulosity;

nevertheless, the stars are very distinct, and the telescope will bear a considerable power.

"(10.)—August 20, 1781. It is so foggy, that I cannot see an object at the distance of 40 feet; yet the stars are very distinct in the telescope. By an increase of the fog, α Piscium can no longer be seen by the eye; yet, in the telescope, it being double, I see both the stars with perfect distinctness." (p. 221.)

"DRY AIR.

"(26.)—Dec. 21, 1782. The tube of my telescope is dry, and I do not see well.

"(27.)—April 30, 1783. The stars are extremely tremulous and confused; the outside of my telescope is quite dry." (p. 222.)

"WINDY WEATHER.

"(31.)—Jan. 8, 1783. It is very windy. The diameters of the stars are strangely increased, even those at 60° and 70° of altitude. Every star seems to be a little planet.

"(32.)—Jan. 9, 1783. Wind increases the apparent diameters of the stars.

"(33.)—Sept. 20, 1783. The night has been very windy; and I do not remember ever to have seen so ill, with such a beautiful appearance of brilliant star-light.

FINE IN APPEARANCE.

"(34.)—May 28, 1781. The evening, though fine in appearance, is not favourable. No instrument I have will act properly. The wind is in the east." (p. 223.)

" OVER A BUILDING.

" (38.)—August 24, 1780. I viewed ε Bootis with 449, 737, and 910, but saw it very indifferently. The star was over a house.

" THE TELESCOPE LATELY BROUGHT OUT.

" (40.)—Oct. 10, 1780, 6h. 30m. Having but just brought out my telescope, it will not act well.

" 6h. 45m. The tube and specula are now in order, and perform very well.

" (41.)—Jan. 11, 1782. To all appearance, the morning was very fine, but still the telescope, when first brought out, would not act well. After half an hour's exposure, it performed better.

" HAZINESS AND CLOUDS.

" (46.)—July 7, 1780. The air was very hazy, but extremely calm.

" I had Arcturus in the field of view of the telescope, and the haziness increasing, it had a very beautiful effect on the apparent diameter of this star.

For, supposing the first of the points, PLATE III. fig. 1, at page 232, to represent its magnitude when brightest, I saw it gradually decrease, and assume, with equal distinctness, the form of all the succeeding points, from No. 1 to No. 10, in the order of the numbers placed over them. The last magnitude I saw it under, could certainly not exceed two-tenths of a second; but was perhaps less than one.

"This leads to the discovery of one of the causes of the apparent magnitude of the fixed stars."—(p. 225.)

The observations which are now before us, appear to be sufficient to establish the following principle; namely,

"That, in order to see well with telescopes, it is required that the temperature of the atmosphere and mirror should be uniform, and the air fraught with moisture."

This being admitted, we shall find no difficulty in accounting for every one of the foregoing observations.

"If an uniform temperature be necessary, a frost after mild weather, or a thaw after frost, will derange the performance of our mirrors, till either the frost or the mild weather are sufficiently settled, that the temperature of the mirror may accommodate itself to that of the air. For, till such an uniformity with the open air, in the temperature of the mirror, the tube,

the eye-glasses, and, I would almost add, the observer, be obtained, we cannot expect to see well."—See observation 15, 17, 18, 19, and 23.

This explains with equal facility, why no telescope just brought out of a warm room can act properly. See *Obs.* 40 and 41.

" Nor can we ever expect to make a delicate observation, with high-magnifying powers, when looking through a door, window, or slit in the roof of an Observatory; even a confined place, though in the open air, will be detrimental."—p. 226.

### CLAMP STAND.

Dr. Derham observes in the preface to his *Astro-Theology*, " the nights that are more than ordinarily serene and clear, are commonly those which are the most intensely cold." In cold weather, the most convenient and steady manner of supporting a Telescope, is by a Clamp* made to fasten on the window sashes when the top sash is put down: the object-end of the Telescope is then in the open air, and if there is no fire in the room, and the Window has been open for half an hour—you will see as well as if you were out of doors.

By this Clamp, we have all the steadiness of being on the Ground, without being exposed to cold and

* Mr. Jones, Optician, at Charing Cross, made me a very complete clamp.

Clamp; I have never seen any Stand more steady than my Clamp on the Sashes is.

Be it always remembered, that *Steadiness* is of the first importance.

When *high Magnifiers* are used, we need every assistance that can be contrived; even with the best constructed Stands, a person walking in the Room, or a Coach within hearing of the rattling of its wheels, will prevent our seeing distinctly; nay, the very pulsation in the body of the observer will sometimes agitate a floor enough to produce this effect; accordingly, in well-constructed Observatories, if the Instruments are not placed on the Ground, or on Stone Pillars, they are supported on one floor, and the Observer stands upon another, which is attached to the Girders and Joists of the Roof.

When we wish to discern those delicate and minute objects, which are the most interesting exhibitions that our Telescopes display to us, and with the finest Instruments are only discernible with the most favourable circumstances, we should be in a position of the greatest ease:—no cramp or painful posture must distort the Body, or irritate the Mind, the whole powers of which must be concentrated in the Eye.

For this reason, Smeaton's Stool, which is adjustable to sit at various heights—and the Box mentioned in the Chapter on *Newtonians* (see p. 142),

are indispensable auxiliaries.—Our Body must be in the easiest possible posture, when we wish our Eye to have all its powers in perfection; and our Seat requires adjusting to heights according to the elevation of our Telescope.—See p. 234.

MR. AUBERT, who built the Observatory at Highbury Place, Islington—had 36 Telescopes; his favourite was a 46 Inch Achromatic—which I purchased of MR. HODGSON, who bought it at Mr. Aubert's sale—this was a very sharp Day Telescope, and had an extremely Steady Stand, and very convenient motions for facilitating Observations, to which I principally attribute Mr. Aubert's partiality to it.

*High Stands for Telescopes for Celestial purposes* should have a Drawer attached to them, to contain the magnifiers, like that in Dr. Herschel's Stand for his 7 feet Newtonian; and should be high enough for the Eye to come conveniently under them, when you are seated in a common chair, when the Tube is elevated to at least 75 degrees.—See p. 221.

The Object-end of Telescopes should be shaded by a DEW-CAP, or Spray-shade—that is, a Brass or a pasteboard tube projecting beyond the Object-end about twice the diameter thereof. This is a convenient auxiliary to defend the Telescope from Dew, and also for observing a Planet or Star near the Moon.

*Those who are extremely susceptible of Cold,* may defend themselves, while observing in the open air, by

a Great Coat lined throughout with Fur, and Throw over that a Woollen Cloak—and put on over their Shoes a pair of the thick woollen Stockings, like those worn by Fishermen, called *Wodmull Hose.*

*The best defence for the Head,* is a couple of the common double Cotton Stocking Nightcaps; their elasticity allows them to be pulled down comfortably close around the Ears and Neck without any resisting pressure.

*For the Throat,* turn up the Collar of Your Great Coat, and tie a Handkerchief round it.

Over all wear a *Black-hood,* which will come down over your Shoulders, similar to that recommended by Sir W. H.—See pp. 304, 5.

This Hood is not only a comfortable Shield against the Chilling night air, but a convenient skreen around the Eye, for preventing the intrusion of any rays upon the retina except those which come direct from the Telescope, and thus, not only improves the Vision very much, but renders it easier to the Eye.—Read page 198.

Those who have not Courage or Constitution to brave the inclemency of Midnight Frosts and Damps, without which, actual Astronomical Observations cannot be made in the Noble Theatre of Nature, I recommend to pay a visit to the

OURANOLOGIA,

in which is shewn the most beautiful and perfect

Orrery ever exhibited—it is one of the most Instructive Exhibitions that Youth can be taken to.

"Stars teach as well as shine."

"An Undevout Astronomer is mad."

"The Heavens are telling the Glory of God, and the Firmament sheweth his handy work."

"These are Thy Glorious Works,
PARENT OF GOOD, ALMIGHTY!"

"A Deity believ'd, is Joy begun;
A Deity ador'd, is Joy advanc'd;
A Deity belov'd, is Joy matur'd."—DR. YOUNG.

This *Lecture on Astronomy and the Phenomena of the Heavens and of the Earth*, which has been writter and compiled by the ingenious Proprietor, is annually given, during Lent, at the ENGLISH OPERA HOUSE, on a Magnificent Orrery of One Hundred and Thirty Feet in circumference. In this immense Machine, the Sun, and all the Planets and Satellites revolving round him, are seen in motion, with their comparative Diameters and Orbits. The whole of the complicated machinery was also invented by MR. ARNOLD.

MR. BARTLEY well deserves the fame he has acquired, by the impressive manner in which he delivers the illustrations of these sublime subjects.

*When you have done using your Telescope*, let the Object-glass, or Object-metal, be taken out and laid in a dry warm room, where the damp air, which on

dewy evenings too plentifully condenses on it, will speedily be evaporated.

However closely the lenses constituting the Object-glass are burnished into the brass Cell, unless they are carefully kept dry, the damp air will penetrate between the Glasses, and produce a sort of Fog, or what Opticians call a sweat, — or sometimes an arborescent vegetation, like sea-weed, which I have seen spread all over the Object-glass; and, for want of attention to the above Caution, many a fine Object-glass has been destroyed by the dampness of the Observatory.

I am informed that this effect of Damp happened very often to the Telegraph Telescopes, and if the Object-glasses were burnished in, the remedy was "*to Roast them*," as they termed placing them before the fire, till the Damp had evaporated.

For ROASTING other Things, the Optician's Oracle, cannot choose but refer the Reader to "THE COOK'S ORACLE."

Unless this Vegetation exists in an extreme degree, experience has proved that the only detriment it does to the performance of the Glass is, that it does not transmit quite so much Light: — if the Instrument be excellent, it is more advisable to put up with an *almost imperceptible* diminution of its brilliancy, than run the risk of destroying a fine Telescope; for an Optician, of great experience, has assured me, that so little Light is intercepted by this vegetation, that

if it was wiped off while you were looking through the Glass, you would not observe any difference.

*Object-Glasses cannot be separated from each other, without perhaps irreparably destroying that harmony from which the Instrument derives its superior excellence, and which, once disturbed, can seldom be restored*—the *Acmé* of perfection being always accidental.

*The Metals of Reflectors which are in Mahogany Tubes are very apt to become tarnished*—especially the Small metals; these, should be covered with a close fitting Brass Cap as soon as done with, and the Large Speculum also. If they get tarnished, nothing removes it better than a little *Citric* acid dissolved in a little water, rubbed on with the finger, and then dried with a bit of quite new and clean Lamb's-skin leather.

At all events, *suffer no one to touch your Telescope but the Original Maker.*—See the *Duke de Chaulnes's* experiment, related in page 8, and the first page of the *Obs.* on *Rigel,* in Chapter XX. of this work.

MEM.—The best time to call and gossip with an Optician, is in hazy weather, when his Galileoship is not engaged in pleasing or teasing his Eye with his Machineries.

## CHAPTER XIX.

### SATURN.

#### THE RING OF SATURN

is visible in an 18 Inch Achromatic Telescope, with a power of 40.—See p. 33.

#### THE BELTS OF SATURN

are not to be seen distinctly in an Achromatic Telescope of less than $2\frac{7}{10}$ths inches aperture (see p. 40), or a Gregorian Reflector of less than 4 inches aperture (see p. 118), nor with a less magnifying power than 80.

The variation of the situation of the Belts of Saturn is much greater than those of Jupiter. Sometimes I have seen only *One* of these Zones, sometimes *Two,*—I never saw *Five*, like the *Quintuple Belt*, drawn by Sir W. H. in vol. lxxxiv. of the *Phil. Trans.*

The Belts on the Body of Saturn are more easily discernible than

#### THE DOUBLE RING.

In extremely fine nights, and when the Planet is in a favourable position for observation, and within

two hours of the Meridian, both the Belts and the Division in the Ring may sometimes be perceived in a fine 44 Inch Achromatic, with an aperture of $2\frac{7}{10}$ths inches, and best with powers of 100 or 130.

On the 24th of November, 1824, at 10 at night, I saw them in an Achromatic of 28 Inches focus, with a double Object-glass of $2\frac{7}{10}$ths inches aperture, with a Single convex Eye-glass, which magnified 115—but these appearances are not visible in a satisfactory manner with an Achromatic unless it has at least $3\frac{6}{10}$ths aperture, or a Gregorian Reflector of 5½ inches aperture.

On December the 20th, 1824, at ¼ past 9; Saturn very near to the Meridian, with a Gregorian, made by Mr. Watson, of 4 inches aperture, and 12 inches focus, magnifying 130, I saw the Division in the Ring, as well as with a 3½ feet Achromatic of $2\frac{7}{10}$ths inches aperture.—See page 297.

The phenomena of this Planet are much easier seen with the 5 Feet, than they are with the 46 Inch Achromatic Telescopes, which have a Treble Object-glass of $3\frac{6}{10}$ths diameter; the superiority of the vision in the 5 Feet, is not to be attributed solely to that Telescope having more Light, because its aperture is $\frac{2}{10}$ths of an inch larger, and its Object-glass is Double instead of Treble; but principally, to the great original power of the Object-glass from its longer focus.—See pages 284 and 289.

This Planet appears brighter, and the Division

between its Rings blacker, and more distinctly with my 5 Feet, with 160, than it does with either my Aubert or Beauclerc 46 inch Telescopes, with 130, or when they have any other power applied to them.

In my 5 feet Achromatic, *The Belts* and *The Division in the Ring*, are easily visible with 100—most pleasantly seen with 130; or, when the Planet is within an hour or two of the Meridian, with 160 or 190 (Huygenian Eye-pieces), beyond the latter, the Planet loses its whiteness and brightness, and its features become less distinct, for want of Illuminating power, and when I increased the Magnifying Power of this Telescope beyond 160, except when the air has been extremely clear, I have felt my Eye immediately regret that the Illuminating power of the Instrument could not be increased in like proportion.

Most of my Observations were made on the North border of London, and the Smoke, &c. thereof, might form a veil against vision, and the Atmosphere be an obstacle against high powers, which may not be in so great a degree in the Country.

Those who wish to see this Planet in London, are advised that they will not discern *the Division in the Ring* so well before—as after 10 o'Clock.

In this " Elysium of Bricks and Mortar" we are so surrounded by " Groves of Chimneys," that until the majority of the Great Fires of the Great Manufactories are out—the obfuscated atmosphere of this

monstrous Metropolis defies all the penetrating power that the immortal Herschel himself could bring against it.

Objects which require all the powers of the Eye to be fresh, and in fine condition, should not be examined when it is tired with having been at work all Day.

If a Planet comes to the Meridian at Midnight, lie down in a quiet darkened room, and rest your Eye by getting a nap. Half an Hour's Horizontal Refreshment, you will find a very renovating preparative for such Contemplation;—it will restore the tone of your Visual Organs, and sharpen your sight prodigiously.—

"Experto crede."

With my 5 feet Achromatic, with 130, the Black Division in Saturn's Ring (when the position of the Planet permits it) is constantly visible; but with higher powers is only to be seen in the fits of easy transmission, and appears like a Mouth opening and shutting: excepting some very fine clear nights, when the air is still, and the Planet within two hours of the Meridian, when I have seen it better with 160,—sometimes, when it has been very near to the Meridian, have used 190 with evident advantage; but have never thought that I saw better with a power beyond that.—See a particular account of the application of Single *Concaves*—*Con-*

*vexes*, and *Huygenian Eye tubes*, to this Planet, in page 60, and the pages following that.

*The proximity of a Planet to the Meridian* is more important with a Small Telescope than it is with a Large one. The same Evening, when Saturn has been not more than 30 degrees above the horizon, with a magnifying power of 200 applied to my Reflector of 9 inches diameter, I have seen the Division in the Ring, when I could not perceive it in a Reflector of 6 inches in Diameter.

Since Sir Wm. H. gave us the Prints of Saturn in the *Phil. Trans.*, some Poor Robin Star-gazers have been sadly dissatisfied with their Glasses, because they would not shew the features of the Planet as large and as plainly as they appear in Sir Wm. H.'s Portraits of them, not considering that Sir Wm. tells us, in page 461 of vol. xcvi. of the *Phil. Trans.*, that "The outlines, and all the other features of the Engravings, of Saturn, are *far more distinct than we can see them in the Telescope at one view;* but it is the very intention of a copperplate, to collect together all that has been successfully discovered by repeated and occasional perfect glimpses, and to represent it united and distinctly to our inspection. Indeed, by looking at the drawings contained in books of Astronomy, this will be found to be the case with them all. For an instance of this, see Tobiæ Mayeri *Opera inedita.* Appendix Observationum ad Tabulam Selenographicam Animadversiones, where the

annexed accurate and valuable plate represents the Moon such as it never can be seen in a Telescope."—See *Phil. Trans.* vol. xcvi. p. 461.

You must not expect to see Saturn so distinctly as it is depicted in these Prints, unless You have an Instrument as powerful and as perfect as that with which the Drawing was made—that is, a Reflecting Telescope of at least $6\frac{3}{10}$ths inches aperture.

Moreover, to have as *Good* a view of Saturn as that given by Sir W. H.—the Planet must be in the same Position—You must have as *Good* an Eye—as *Good* a Telescope,—in as *Good* Adjustment*,—in as *Good* Temper;—the Stand of the Telescope must be *Good*,—and it must be placed on *Good* firm Ground in a *Good* situation in a *Good* clear Evening.

Sir Wm. H.'s 7 feet Newtonian, with which he informs us that most of his observations on Saturn were made, had an aperture of only $6\frac{3}{10}$ths inches, and magnified with its single Convex Lens 287; but with the fellow Telescope to that, which I have, made by Sir W. H. (see page 141 on the 7 *Feet Newtonian*), I find 250 to be quite the maximum of power that I wish to use at Saturn;—and with that power, unless the observer has a very different Eye to mine, he will not see the Planet half so big

* A very useful term in Optics, which, like *Nervous* in Physic, serves to account for all kinds of unaccountable derangements and non-performances in Optical machineries.

as it is represented in Sir Wm. H.'s portraits, in all of which the Body of the Planet is 1$\frac{7}{10}$ths inches in diameter.

In the Drawing in the Frontispiece, which was made with a Herschel 7 feet Newtonian, with a Huygenian Eye-tube of 213, the Body of Saturn appears very little more than $\frac{6}{10}$ths of an inch in diameter: with my 5 feet Achromatic, with 190, it appears rather less, nor have I met with any Eye that, with these Instruments and powers, estimated it larger :—it would be a deviation from that strict Truth, which it has ever been my earnest endeavour exactly to observe, to portray a Planet larger than it appeared in my Glass.

HUYGENS, in his *Systema Saturnium,*" 4to, 1659, p. 55, has given us a Portrait of Saturn, in which the body of that Planet is 1$\frac{3}{10}$ths inches in diameter, and from one extremity of the Ring to the other 3$\frac{1}{8}$th inches; this was made with a Refractor of 23 feet focus, which Dr. Long (in page 464 of the 2d vol. of his Essay on Astronomy, 4to, 1785,) says, magnified 100 times :—there is no Belt on the Body, nor Division in the Ring, in this large Portrait, which is in the same position, and in shape and proportion is similar to Sir Wm. H.'s, only that it is a little less, and there is no Quintuple Belt, nor Division in the Ring; see Sir Wm. H.'s print in the *Phil. Trans.* for 1794—which was made with his 7 feet Newtonian, with a Metal of 6$\frac{3}{10}$ths inches in

diameter, and a single convex Eye-glass which gave a magnifying power of 287.

Mr. HADLEY'S Portrait of Saturn, which was taken in June 1720, and is in Dr. LONG'S Astronomy, and in the *Phil. Trans.* is the first print which gives us any thing like a real resemblance of

THE DIVISION IN THE RING,

which in this print is represented *as broad as the Outer Ring*, which is near to the fact: Dr. LONG says, " Upon my asking Mr. Hadley* whether the

* Sir I. Newton's Telescope having lain neglected for 50 years, was executed by Mr. Hadley.—See *Phil. Trans.* for 1723, vol. xxxii. pp. 303 and 382, which contains a particular account of it; as does also Gregory's Optics, by Desagulier, 8vo, 1735. p. 244.

" The large Speculum of Mr. Hadley's Telescope was 6 inches aperture, and 5 feet 2⅝ths inches focus, and half an inch in thickness: The oval plane is $\frac{1}{15}$th or $\frac{1}{16}$th of an inch in thickness, soldered on the back to another of brass; its breadth something less than half an inch, and is in proportion to its breadth as 1 to $\sqrt{2}$: had three single Eye-glasses magnifying about 190, 208, and 230 times, and a Day Eye-tube 125 times."—In vol. xxxii. of the *Phil. Trans.* for 1723, p. 384.

" It is no small convenience, that by means of one of these reflecting Telescopes, whose Length exceeds not five Feet, (and which may be managed at a Window within the House,) Celestial Objects appear as much magnified, and as distinct, as they do through the common Telescope of more than 100 Feet in Length.

Planet appeared as distinct as in the figure engraved? he answered, 'That if the figure were

" *Mr. Bradley*, the *Savilian* Professor of Astronomy, and myself, have compared *Mr. Hadley's* Telescope (in which the focal length of the Object-metal is not quite 5 feet and ¼,) with the *Huygenian* Telescope, the focal length of whose Object-glass is 123 Feet: and we find, that the former will bear such a charge, as to make it magnify the Object as many Times as the latter with its due charge; and that it represents Objects as distinct, though not altogether so clear and bright; which may be occasioned partly from the difference of their apertures (that of the *Huygenian* being somewhat the larger), and partly from several little spots in the concave Surface of the Object-metal, which did not admit of a good polish.

" Notwithstanding this difference in the brightness of the Objects, we were able, with this reflecting Telescope, to see whatever we have hitherto discovered by the *Huygenian*; particularly the Transits of *Jupiter's* Satellites and their Shades, over the disk of Jupiter; the black List in *Saturn's* Ring; and the Edge of the Shade of *Saturn* cast on the Ring, as represented by Fig. 4, Plate II. of the fore-mentioned *Transact.* No. 376.

" We have also seen with it, several times, the 5 Satellites of *Saturn*; in viewing of which this Telescope had the advantage of the *Huygenian*, at that time when we compared them; for it being in Summer, and the *Huygenian* Telescope being managed without a Tube, the twilight prevented us from seeing in this some of those small Objects, which, at the same time, we could discern with the reflecting Telescope.

" I am, &c.

" Ja. Pound."

" In observing *Saturn* the last Spring, at a time when the Planet was about 15 days past the Opposition, he saw the Shade

placed at thedistance of 5 or 6 feet, it would, to Eyes of the common sort, give a very good representation of what his Telescope shewed to him.'"

*The Division in Saturn's Ring*

most of the drawings represent as in the centre of the Ring, and as dividing it into two equal parts— Sir Wm. H., in his drawing with the Quintuple Belt, makes the Inner Ring as 3 parts, and the Outer as

of the Planet cast upon the Ring, and plainly discerned *the Ring to be distinguished into two Parts by a dark Line,* concentric to the circumference of the Ring. The outer or upper part of the Ring seemed to be narrower than the lower or inner part next the Body, and the dark Line, which separated them, was stronger next the Body, and fainter on the outer part, towards the upper edge of the Ring. Within the Ring he discerned two Belts, one of which crossed *Saturn* close to its inner edge, and seemed like the Shade of the Ring upon the Body of Saturn; but when he considered the situation of the Sun, in respect to the Ring and *Saturn,* he found that Belt could not arise from such a Cause.

" *The dark Line on the Ring of Saturn,* parallel to its circumference, is chiefly visible on the *ansæ,* or extremities of the Elliptic Figure, in which the Ring appears; but he has several times been able to trace it very near, if not quite round; particularly in May, 1722, he could discern it without the Northern Limb of Saturn, in that part of the Ring that appeared beyond the Globe of the Planet."

The above are Mr. Hadley's Observations with the same Telescope.—See *Phil. Trans.* for 1723, vol. xxxii. pp. 385—6.

For an account of a Newtonian, made by Mr. Dollond for Mr. Dunn, vol. lii. p. 188.—Mag. 220.

one, of the whole Ring: and the Outer Ring about twice as broad as the Division between it and the Inner Ring.

To my Eye *the breadth of the Outer Ring* appears to be about one-fourth more than the Division between it and the Inner Ring.

*The breadth of the whole Ring* (including the division in it) is to the space between the Ring and the body of Saturn as about 5 to 4, which is according to Sir W. H.'s calculation.—See the *Phil. Trans.* vol xcvi. p. 463.

It had the above appearance in 1825, on April 2, 8 o'clock, with a 12 feet Achromatic, of 7 inches aperture, made by Mr. TULLEY—with 150, the 7 Satellites of Saturn were easily visible—not so easily with 200—the Planet appeared as bright as brilliantly burnished Silver, and I saw the Division in the Ring, and a Belt, very plainly with 200.

April 4, I again saw the two extremely faint points of Light which I, on the 2d, conjectured were the 6th and 7th Satellites of Saturn—and have now no doubt that they are—as their relative position to each other, and to the Planet, is considerably changed since the 2d; with 150 they appeared as the small Star, which accompanies the Pole Star, does in a fine 5 feet Achromatic of $3\frac{6}{10}$ths inches aperture, with a power of 100.—N.B. I believe that is the only observation recording these Satellites, except those of Sir Wm. H.'s.—See

an Observation on the Pole Star with this 12 feet Achromatic, under the Article *Pole Star*, in the Chapter on *Double Stars*.

The diameter of the Body of Saturn in Mr. Hadley's engraving is $\frac{7}{10}$ths of an inch, which corresponds very nearly with the size which I have delineated it.

*A Vulgar Error* prevails, that if a Small Telescope magnifies as much, you can see as well with it as with a Large one—the needful proportion of Illuminating power by which Magnifying power must be supported to be effective, has never been fully explained till the writer of this work wrote the 17th Chapter of this Book, to page 248 of which he refers the Reader.

In composing this work, I have always considered myself as addressing a Novice, who has had very little acquaintance with the subjects which I am endeavouring to elucidate;—I therefore must observe, that *the visibility of the Division in the Rings of Saturn*, depends upon the position of that Planet: I have heard persons complain of their Telescopes, when the only reason why they could not see the Division in the Rings, was, because, from its peculiar position, "it was not in sight."

*The Singular figure of which the Body of Saturn* was observed by Sir W. H. on April 19, 1805, when he says, that "the Figure of Saturn is somewhat like a parallelogram, with the four corners rounded off deeply, but not so much as to bring it

to a Spheroid"—the polar diameter was 32, the Equatorial diameter was 35, as portrayed in Sir W. H.'s print, which the reader will find, with a description thereof, in the 455th page of the *Phil. Trans. for* 1806,—is very like the appearance which the Planet presented, in September 1818, when I made a sketch of it, which is like to Sir W. H.'s; only that in my sketch the Body of the Planet is about ½ an inch in diameter, which was the size that it appeared to my Eye with the *Beauclerc* 46 inch Achromatic, which has a Treble Object-glass of $3\frac{6}{10}$ths inches aperture, and a Magnifying power of 130—and with a 10 feet Achromatic, with an aperture of 4 inches, a power of 120—and that in Sir W. H.'s portrait the Body of the Planet is $1\frac{7}{10}$ths inches in its widest diameter, and that I could not then see any Division in the Rings—there were two Belts visible; but the Ring was in that position when the Division in it was not visible — at least not in the Telescopes which I used.

I have occasionally observed this Planet for nearly 30 years, and I do not remember to have seen the Body of it of this singular form, except for a few months at the time I have mentioned.

Sir W. H. says, in page 458 of the *Phil. Trans.* for 1796, that " an Observer who has not an Instrument that will bear a very distinct Magnifying power of 500, ought not to expect to see the outlines of Saturn so sharp and well-defined as to have a right

conception of its figure."—However, in September 1818, the singular figure of it was easily seen, even in a 30 Inch Achromatic, of only 2 Inches Aperture, and power of 100.—*The outlines of the Planet* do not require half so much Illuminating or Magnifying Power, as is required to see *the Belts*, and *the Division in the Rings*.

I mention these particulars, because I have met with several persons whose Candour had conquered their Courtesy so completely, that they said, that this extraordinary portrait of Saturn is not a proof of the goodness of Sir W. H.'s Telescopes, but a proof that they represented Objects distorted.

*The Body of Saturn* (according to my recollection) *appeared of this shape only for a few months;* and some persons who had not been continually observing the Planet, and who were not aware of the humpty-dumpty shape which it had assumed, when they saw it, a few months after, when it had returned to its usual form, doubted the correctness of Sir W. H.'s portrait.

However, the Prints of *Saturn*, which have since that time been given in the Encyclopædias and Elementary works on Astronomy, are, I believe, all taken from this humpty-dumpty portrait—that being the latest likeness drawn by Sir W. H., I suppose it has been by the Editors of these works considered the best.

It would be an extremely acceptable acquisition to

Astronomers and Opticians, and will immortalise any accurate Observer, who will be so industrious, to give a new Edition of the Figures of the Humble, the Honest, and the Pains-taking HUYGENS, on a Scale sufficiently large to shew the appearance of this wonderful Planet, in each year of its Revolution; or, as it appears, in each of the Signs of the Zodiac —(see following page):—this would teach those who are curious about it, when they might expect to see the Planet in its various positions; when the Division in the Rings appears most plainly—when it vanishes to a mere bar across the Planet—and when it appears only as a Belt, as Sir W. H. has represented it in his prints in the *Phil. Trans.*

Sir. Wm.'s Print, in the *Phil. Trans.* vol. lxxx. represents *the ring reduced to a bar* across the Planet, as seen by him, with a Newtonian of 5½ feet focus, on the 17th March, 1774.

Another Drawing, which was made with the same Telescope, on the 3d April, 1774, shews it as *a mere Belt.*

In the same vol. at page 20, are two drawings, made with a 10 feet Newtonian, which shew *the Ring, when open,* on the 20th June, 1778—and on the 11th May, 1780, in the same vol. there is also a diagram of the 7 Satellites of Saturn.

In vol. lxxxiv. is his Account of, and Print of, *the Quintuple Belt,* as it appeared in a 7 feet Newtonian, on the 11th Nov. 1793.

In vol. xcvi. pp. 272 and 455, are his Papers "*on the Singular Figure of the Planet Saturn*," and Two Engravings of it.

The Print of this Planet in the Frontispiece to this work was made in March 1825, as it appeared in my 7 feet Herschel Newtonian, with an aperture of $6\frac{3}{10}$ths inches, and power of 213, and a 5 feet Achromatic, of $3\frac{8}{10}$ths inches aperture, and power 190, — the body appearing a little smaller in the Achromatic than in the Newtonian.

" In HUYGENS's *System of Saturn*, 4to, 1659, p. 55, is a perspective view of the orbit of the Earth, and the orbit of Saturn, with the Sun in the centre of them : at *a*, *b*, *c*, *d*, &c. is exhibited Saturn, with his Ring continually parallel to itself, during a 30 years revolution through his orbit: at the corresponding capitals A, B, C, D, &c. are shewn the various forms under which the Ring appears to us: thus, when Saturn is in the ascending node of the Ring at *a*, he appears round, as at A; the Ring being then not visible : at *b*, the Ring appears as at B; at *c*, as at C, &c. an ellipsis very narrow at first, with the ends of it sharp, but growing continually wider, till Saturn arrives at *f*, a quarter of a circle from the ascending node of the Ring, there the ellipsis appears as at F, the widest that it ever can be ; and from thence grows gradually narrower, and the ends of it, or the *ansæ*, appear sharper and sharper, all the way to the descending node of the

Ring at *i*, where the Ring again disappears, and we again view Saturn round, as at *i*: from thence, during the other half of Saturn's period, we see the Ring appear as an ellipsis wider and wider, till he is gotten 90 degrees from the descending node, where it is again at the widest; and then becomes gradually narrower, till its totally disappearing at the ascending node at *a*.

"1135. It is very easy to see by the figure, that, while Saturn is going through one-half of his orbit from *a*, through *b*, *c*, *d*, &c. to *i*, the Northern or upper side of the Ring is illuminated by the sun; but in going through the other half, from *i* through *k*, *l*, *m*, &c. to *a*, the Southern or lower plane of the Ring receives his light: it is evident, also, from the figure, that when the Ring is in either of its nodes, the rays of the Sun fall upon the edge thereof; and, when near the nodes, they fall upon one of the planes of the Ring with great obliquity, and consequently throw very little light thereon; and that the farther the Ring is from its nodes, the stronger is the light upon it: for it then falls upon it most directly, and therefore Saturn then appears brightest to the Eye, unassisted with Glasses."—Dr. LONG's *Astronomy*, 4to, 1785, pp. 466—7.

The earliest account which I have met with of an observation of *the Division in Saturn's Ring*, is in the *Phil. Trans. for* 1666, by Mr. WM. and Dr. BALL, on October the 13th, 1665, at 6 o'clock, with a

very good Telescope, near 38 feet long, and a double Eye-glass. This observation has induced the supposition, that Saturn is surrounded not by *one* circular body or ring only, but by *two*."

According to Huygens' table of the Focal lengths and apertures of Reflecting Telescopes, in Dr. Smith's Optics—the Aperture of an Object-glass of 38 feet focus was $3\frac{3}{10}$ths inches, and magnifying power 116 times—a Telescope so long and so large must be bad indeed, if it did not shew the division in the Ring pretty plainly.

See a portrait of *Saturn,* made with a 60 feet Refractor, by Dr. HOOK, in vol. i. of *Phil. Trans.* p. 246.

There is another made by HUYGENS, with a 21 feet, in the 4th vol. of *Transactions* for 1669, p. 900—(another by Mr. Hook, in 1670, in vol. v. p. 2083,) in vol. vi. p. 3024, and by Mr. Flamstead, p. 3034, with a 14 feet Telescope of 1½ inch aperture.

See a description and a drawing of the *Division in Saturn's Ring,* as seen by *Cassini,* with Refractors of 35 and 20 feet focus, in *Phil. Trans.* for 1676, vol. xi. p. 690—the Refracting Telescope of 20 feet focus, had an aperture of not quite 2½ inches, and power of 90.

" In the bright part of each *ansa,* was a darkish ellipsis, nearer to the outside than to the inside of the Ring, as if it was composed of two rings, near to one another."

"On the Body of Saturn, besides the Ring on the *South*-side, there appeared on the *North*-side, a zone, not so far from the centre of the Ring, and not much unlike the smallest of *Jupiter's* Belts. These appearances were first taken notice of by *Mr. Cassini, in Phil. Trans.* No. cxxviii. p. 690—Fig. 19.

The above are Mr. Pound's Observations with the Huygenian Aerial Glass, of 123 feet focus, and 6 inches aperture, in 1713, in p. 773 of vol. xxx. of the *Phil. Trans.* in which there is a drawing of Saturn.

"1132. In the year 1675, after Saturn had emerged from the sun's rays, Sig. Cassini saw him, in the morning twilight, with a darkish belt upon his globe, parallel to the long axis of his ring, as usual. But, what was most remarkable, the broadside of the ring was bisected quite round by a dark elliptical line, dividing it, as it were, into two rings, of which *the inner Ring* appeared brighter than the *Outer one,* with nearly the like difference in brightness, as between that of silver polished and unpolished; which, though never observed before, was seen many times after, with tubes of 34 and 20 feet; and, more evidently in the twilight or moonlight, than in a darker sky."—Dr. SMITH'S *Optics,* 4to, 1738, vol. ii. p. 440.

## OF THE SATELLITES OF SATURN.

*Sir William Herschel* observes, that the visibility* of these minute and extremely faint objects, depends more on the *Penetrating* than upon the *Magnifying* power of our Telescopes: and that " with a 10 feet Newtonian, charged with a Magnifying power of only 60, Sir W. H. saw all the 5 old Satellites;" (see his *Obs.* on the 19th Dec. 1793—1h. 56m. in the *Phil. Trans.* vol. lxxxiv. p. 56,) but the 6th and the 7th, which he informs us were discovered, and were easily seen with his 40 feet Telescope, and were visible in his 20 feet, were not discernible in the 7 or the 10 feet, though *all that Magnifying power can do, may be done as well with the 7 feet as with any larger Instrument.*

" August the 28th, 1789. Having brought the 40 feet Telescope to the parallel of Saturn, I discovered *a 6th satellite* of that planet; and also saw the spots upon Saturn better than I had ever seen them before, so that I may date the finishing of the 40 feet Telescope from that time."—Sir Wm. H.'s Paper, in vol. lxxxv. of the *Phil. Trans.*

Speaking of the 7th Satellite of Saturn, Dr. H. says, " Even in my 40 feet Reflector it appears not bigger than a very small lucid point. I see it, how-

* See my *Obs.* of them, in p. 348, with a power of 150.

ever, also very well in the 20 feet Reflector; to which the exquisite figure of the Speculum not a little contributes."—See *Phil. Trans.* vol. lxxx. p. 12, of Dr. H.'s account of the Discovery of a 6th and 7th Satellite of the Planet Saturn, and the construction of its Ring.

See on the Satellites of the Planet Saturn, and the Rotation of its Ring on an Axis, by Dr. HERSCHEL.—*Phil. Trans.* for 1790, vol. lxxx. p. 427.

With this paper " is given a scheme, wherein the orbits of the Satellites of Saturn are drawn in their due proportions. A few words will explain the construction and use of this figure, which, notwithstanding its simplicity, is yet amply sufficient to ascertain the accuracy of every observation." p. 429.

This interesting paper occupies 68 pages.

Several observers have assured me, that they have seen all *the 5 old Satellites* in a 5 feet Achromatic, with an Aperture of $3\frac{8}{10}$ths inches, and a power of 60.

Mr. BUTT, of Bath, informed me, that he saw them in his $3\frac{1}{2}$ feet Achromatic, which has an Aperture of $2\frac{7}{10}$ths inches, by placing a patch before that part of the field of the Telescope where Saturn appeared, and thereby enabling the Pupil of the Eye to expand and adjust itself for discerning the fainter objects of the Satellites.

The minute Stars which accompany some Large Stars—for instance the very faint star near *α Lyræ*

is visible when the large Star is out of the field, with a Telescope with which it is not discernible, while the brilliance of the large Star is stimulating and shutting up the Pupil.

There is an account of the discovery of Two Satellites by Cassini, in vol. vii. p. 5178, of the *Phil. Trans.* with a 17 feet Refractor, made by Campani; and of Two others, in March 1684, by Cassini.—See *Phil. Trans.* for 1686, vol. xvi. pp. 79 and 83.

" *The Satellites of Saturn were first of all seen in March, Anno* 1684, by two excellent Object-glasses of 100 and 136 *feet;* and afterwards by two others, of 90 and 70 *feet*, all made by *Sig. Campani,* and sent from *Rome* to the Royal Observatory at Paris, by the King's order, after the discovery of the third and fifth *Satellites,* which had been made by others of his Glasses of 47 and 34 *feet.* We made use of them without *Tubes,* by a more simple contrivance than those proposed either before or since. We have since seen all these *Satellites* with that of 34 *feet,* with an aperture of $3\frac{3}{10}$ths inches, and continued to observe them with these Glasses of Mr. Borelli, of 40 and 70 *feet,* and by those which *Mr. Artouquel* hath lately made, of 80, 155, and 220 *feet.* It was easy for us to see these two *Satellites* by these different sorts of Glasses, after having found the Rules of their Motion, whereby we might, with

more particular attention, look upon the places where they ought to be."—See *Phil. Trans.* for 1686, p. 83.

Dr. Derham, in the Preface to his *Astro-Theology*, says, "I remember that I once verily thought I had found out 7 *Satellites of Saturn*, with this very glass of *Mr. Huygens*, so regularly were they placed in respect of Saturn. But when I came to examine them the following nights, I found that there were really no more than two Satellites, the rest being small fixed stars. But Mr. Pound's skill and exactness in such observations is, I know, so great, (and I may add, that of my sagacious friend, Dr. Halley, too, who, I hear, hath seen the same,) that I do not say this by way of caution to them, although it may serve as such to many others."

## SIR WILLIAM HERSCHEL'S OBSERVATIONS ON SATURN.

These are dispersed through many Volumes of the *Philosophical Transactions*, and I thought that to bring together the more remarkable passages into one view, would be an act of industry, which the Reader would thank me for.—They are copied in Sir Wm.'s own words, and references attached to the *Vol.* where they are to be found.

I have not arranged them in chronological order—

but in that which the concatenation of the subjects treated of suggested.

"There is not, perhaps, another object in the heavens that presents us with such a variety of extraordinary phenomena as the planet Saturn: a magnificent globe, encompassed by a stupendous double ring: attended by seven satellites: ornamented with equatorial belts: compressed at the poles: turning upon its axis: mutually eclipsing its ring and satellites, and eclipsed by them: the most distant of the rings also turning upon its axis, and the same taking place with the farthest of the satellites: all the parts of the system of Saturn occasionally reflecting light on each other: the rings and moons illuminating the nights of the Saturnian, the globe and satellites enlightening the dark parts of the rings: and the planet and rings throwing back the sun's beams upon the moon's, when they are deprived of them at the time of their conjunctions.

"It must be confessed, that a detail of circumstances like these appears to leave hardly any room for addition; and yet the following observations will prove that there is a singularity left, which distinguishes the figure of Saturn from that of all the other planets."

"April 12th, 1805. With a new 7 feet mirror of extraordinary distinctness, I examined the planet

Saturn. The *Ring* reflects more light than the *Body*· and with a power of 570, the colour of the body becomes yellowish, while that of the ring remains more white. This gives us an opportunity to distinguish the ring from the body, in that part where it crosses the disk, by means of the difference in the colour of the reflected light."

" *The Light of the Ring of Saturn* is generally brighter than that of the Planet.

" March 11th, 1780. I tried the power of 222, 332, 449, successively, and found the light of Saturn less intense than that of the Ring; the colour of the Body, with the high powers turning to a kind of yellow white, that of the Ring still remained white."—Dr. H. in *Phil. Trans.* vol. lxxx. p. 5.

" ON THE DOUBLE RING OF SATURN.

" The planet Saturn has two concentric rings, of unequal dimensions and breadth, situated in one plane, which is probably not much inclined to the equator of the planet. These rings are at a considerable distance from each other, the smallest being much less in diameter at the outside than the largest is at the inside.

" The dimensions of the two rings, and the intermediate space, are nearly in the following proportion to each other :—

| | |
|---|---|
| "Inside diameter of the smallest ring | 5900 parts |
| Outside diameter | 7510 |
| Outside diameter of the largest ring | 7740 |
| Outside diameter | 8300 |
| Breadth of the inner ring | 805 |
| Breadth of the outer ring | 280 |
| Breadth of the vacant space | 115 |

"Admitting, with M. DE LA LANDE, that the breadth of the whole ring, as formerly supposed to consist of one entire mass, is near one-third of the diameter of Saturn, it follows that the vacant space between the two rings, according to the above statement, amounts to near 2513 miles."—Dr. HERSCHEL, in *Phil. Trans.* vol. lxxxii. pp. 4 and 5.

In the *Phil. Trans.*, vol. lxxxii. at pp. 3 and 4, we have :—

"October 24, 1791. 7 feet Reflector, with a new *Machine-polished* most excellent Speculum, I see that the Division in the Ring of Saturn, and the open space between the Ring and the Body, are equally dark, and of the same colour with the heavens about the Planet.

"20 feet Reflector, with a power of 600, I can trace the Division very nearly as far as the place where a perpendicular to the direction of the Ring would divide the open space between the Planet and the Ring, into Two equal parts."

"*The Outer Ring* is less bright than *the Inner** *Ring*. The Inner Ring is very bright close to the dividing space; and at about half its breadth, it begins to change colour, gradually growing fainter, and just upon the inner edge, it is almost of the colour of the dark part of the quintuple belt." p. 53.

"QUINTUPLE BELT.

"Nov. 11, 1793, 3h. 35m. 7 feet Reflector, power 287.

"Close to the Ring of Saturn, where it passes across the body of the planet, is the shadow of the Ring; very narrow, and black.

"Immediately south of the shadow is a bright, uniform, and broad belt.

"Close to this bright belt is a broad darker belt,—which is divided by two narrow white streaks; so that by this means it becomes five belts; namely, three dark and two bright ones; the colour of the dark belt is yellowish."—See the above, and a Plate of the *Quintuple Belt*, by Dr. HERSCHEL, in *Phil. Trans.* vol. lxxxiv. p. 28.

* I differ with Dr. H. respecting the Magnifying power necessary to shew the shape of Saturn.—I saw this Sept. 13th, 1818, with my Beauclerc 46 Inch — with 130 — perfectly well, and made a drawing of it, in which the shape of the body of the Planet, with his belts, is very like to that of Dr. H.'s plate, which accompanies his Paper, in the *Phil. Trans.* vol. xcvi. p. 455.—See page 350 of this work.

"OBSERVATIONS ON THE BELTS OF SATURN.

"In the course of these observations, I made 10 new Object-specula, and 14 small plain ones, for my 7 FEET REFLECTOR; having already found, that with this instrument I had *light sufficient to see the belts of Saturn completely well;* and that here, the maximum of distinctness might be much easier obtained, than where large apertures are concerned.

"I found that the strong light of THE 20 FEET REFLECTOR was too great a fatigue for the eye, which cannot bear to look at a very luminous object for a long time together. For this reason, I chiefly used the 7 feet Reflector; and in future, all the observations not expressly marked otherwise, are to be understood as having been made with that instrument; bearing an Eye-glass of $\frac{3}{10}$ths of an inch focal length. My Object-specula are generally from 84 to 88 inches in focus, and therefore give a power from 280 to 293. The favourite one gave 287. I had another reason for chiefly confining myself to one instrument and one power, which was, that every circumstance being as much as possible the same, a change in the object I viewed might be the sooner perceived."— Dr. H. in *Phil. Trans.* vol. lxxxiv. p. 51.

"ON THE SINGULAR FIGURE OF THE PLANET SATURN.

"The use of various Magnifying powers in observing minute objects, is not generally understood.

A low power, such as 200 or 160*, with which I have seen the figure of Saturn, is not sufficient to shew it to one who has not already seen it perfectly well with an adequate high power; an observer, therefore, who has not an instrument that will bear a very distinct Magnifying power of 500†, ought not to expect to see the outlines of Saturn so sharp and well defined, as to have a right conception of its figure."—*Phil. Trans.* vol. xcvi. p. 272.

---

## JUPITER.

" The strongest and most remarkable

BELTS OF JUPITER

may be easily seen in an 18 Inch Achromatic, or a 1 foot Reflector, with a Magnifying power of 40.—See pp. 33, 58, and 116.

* This does not correspond with the 3d paragraph in p. 279, of vol. xcvi. of the *Phil. Trans.* in Dr. H.'s preceding paper, on the Singular figure of the Planet Saturn. " With 200 I saw the difference very plainly, and even with 160, it was sufficiently visible to admit of no doubt. These low powers shew the figure of the planets perfectly well."—See my Obs. with a 30 Inch Achromatic in p. 351 of this work; and the note at foot of p. 364.

† Is there a Telescope in the Universe that will bear a Magnifying Power of 500 for Planetary Observations, so distinctly as one of 250? " *The Cook's Oracle*" declares NO.

"The principal belts in Jupiter are equatorial, and as we have certain constant winds upon one planet, especially near the equator, that regularly for certain periods blow the same way, (see *Acta Eruditorum*, 1687, Dr. HALLEY'S *Account of the Periodical Winds*,) it is easily supposed that they may form equatorial belts, by gathering together the vapours which swim in our atmosphere, and carrying them about in the same direction. This will, by analogy, account for all the irregularities of *Jupiter's* revolutions, deduced from spots on his disk, that may have changed their situation."—Dr. HERSCHEL'S *Obs.* on *Jupiter*, 1778, in the *Phil. Trans.*—and see the Rev. F. WOLLASTON'S Paper on *Jupiter*, with 9 Portraits of that Planet, in vol. lxiii. of the *Phil. Trans.* p. 75.

THE MOONS OF JUPITER

are easily visible in a 1 foot Achromatic Spy-glass, with the ordinary Day Eye-tube, which magnifies about 16 times—they may be seen with half that Magnifying Power, indeed I have heard of people who pretended that they could see them with their naked Eye—but I believe that they were mistaken.

The Moons appear larger, and with a defined disk like Planets, in proportion as we see them through a large and perfect Telescope.

See in vol. lxxxvii. of the *Phil. Trans.* page 332, Dr. HERSCHEL'S *Observations* of the changeable Brightness of the Satellites of Jupiter, and of the

variation in their apparent Magnitudes; with a determination of the time of their rotatory Motion, on their Axis. To which is added, a Measure of the Diameter of the Second Satellite, and an estimate of the comparative size of all Four."

## CHAPTER XX.

SIR WM. HERSCHEL'S DISCOVERIES OF DOUBLE STARS, AND OF THE TELESCOPES, AND POWERS PROPER FOR OBSERVING OF THEM.

MOST of the modern discoveries in Astronomy have been made by Sir WILLIAM HERSCHEL:—these have not arisen so much from the extraordinary Magnitude, as from the *extraordinary Perfection* of his Optical Instruments*, and from his *incomparable Skill* and his *indefatigable Perseverance* as an Observer.

Astronomers and Opticians are greatly indebted to Sir Wm. for the time and labour that he devoted in making experiments to ascertain the powers of Reflecting Telescopes, which it is presumed, that the happy combination of Perseverance

* "It is a Vulgar Error, that the discoveries of Dr. Herschel have been occasioned by the enormous Magnifying power of his Telescopes; the fact is, that no such large power is necessary or useful; and that all Dr. Herschel's discoveries have been made with Reflectors of from 7 to 20 feet, and with powers of from 60 to 300. His discoveries are to be attributed to his laudable perseverance, and not to the size of his great Telescope." — *British Crit. Charac.* for 1798—8vo. p. 365.

and Skill of which Sir Wm. had so large a share—enabled him to carry to the "*ne plus ultra*," both in perfection and magnitude, having built a *Stupendous Telescope* of the length of 40 *Feet*—with an aperture of 4 *feet*. Of the performance of this enormous Engine I cannot speak, never having seen through it: however, for his perseverance in constructing such a Gigantic Optical Instrument, his name must be ever remembered with admiration and gratitude, by every Optician and Astronomer.

Here let me pay the just tribute of well-deserved praise to the unparalleled perseverance this ingenious Astronomer has manifested in composing his CATALOGUE of DOUBLE STARS, which must for ever remain an indelible memorial of the determined ardour with which he so successfully pursued his favourite Study.

Dr. Herschel, in p. 249 of vol. lxxiii. of *Phil. Trans.* informs us, that his "*First Review* of the Stars was made with a Newtonian Telescope of not quite 7 feet focus, and with an aperture of only 4½ inches, charged with a power of 222. It extended to Stars of the 1st, 2d, 3d, and 4th magnitudes."

"Of my *Second Review*, I have already given some account in the *Phil. Trans.* vols. lxxi., lxxii., lxxiii. This was made with a Telescope of similar construction, but much superior to the former, with an Object-metal of 85, 2 inches focus, and 6¼ inches diameter, and magnifying 227 times. It extended

to all the Stars in HARRIS's Maps, and the telescopic ones near them, as far as the 8th magnitude. The *Catalogue of Double Stars,* which I have had the honour of submitting to the Royal Society, and the discovery of the *Georgium Sidus,* were the result of that review."

"My *Third Review* was made with the same Instrument and aperture, excepting the eye-glass, which was changed for one which gave the Telescope a very distinct magnifying power of 460." This, the Doctor says, was much superior to that of 227, in detecting excessively small stars, and those which are very near to large ones. He informs us, that he "had 18 higher magnifiers, which gave him a gradual variety of magnifying powers from 460 to 6000, in order to pursue particular objects to the full extent of my Telescope, whenever a favourable interval of remarkably fine weather presented me with a proper opportunity for making use of them."

"This review extended to all the stars in FLAMSTEAD's Catalogue, together with every small star about them, as far as the tenth, eleventh, or twelfth magnitudes, and occasionally much farther, to the amount of a great many thousands of stars. To shew the practicability of what I have here advanced, it may be proper to mention, that the convenient apparatus of my telescope is such, that I have many a night, in the course of eleven or twelve hours of observation, carefully and singly examined not less

than 400 celestial objects, besides taking measures of angles and positions of some of them with proper Micrometers, and sometimes viewing a particular Star for half an hour together, with all the various powers of my Telescope."

"The particulars I attended to in this last review were: 1. The existence of the Star itself, such as it is given in the British Catalogue.

"2. To observe well whether it was double or single, well-defined or hazy.

"3. To view and mark down its particular colour, whenever the altitude and situation of the Star would permit it to be done with certainty.

"4. To examine all the small stars in the neighbourhood, as far at least as the twelfth magnitude, and note the same particulars concerning them, except the colours, which would have taken up too much time in committing to paper, and be of no material use."—Dr. Herschel's Paper in the *Phil. Trans.* vol. lxxxiii. p. 250.

As Mathematician — Optician — Mechanist — and Observer combined, — Dr. H., excepting his predecessor, *Huygens*, stands alone in the annals of Optical and Astronomical Science — indeed, such Tools as he worked with could only be made by the man who used them, and only be used by the man who made them.

The following is an Account of some of his labours in Telescope-making, in his own words.

"When I resided at Bath, I had long been acquainted with the theory of Optics and Mechanics, and wanted only that Experience which is so necessary in the practical part of these Sciences. This I acquired by degrees at that place, where, in my leisure hours, by way of amusement, I made for myself several 2 feet, 5 feet, 7 feet, 10 feet, and 20 feet, NEWTONIAN telescopes; besides others of the GREGORIAN form, of 8 inches, 12 inches, 18 inches, 2 feet, 3 feet, 5 feet, and 10 feet focal length. My way of doing these instruments at that time, when the direct method of giving the figure of any of the conic sections to specula was still unknown to me, was, to have many mirrors of each sort cast, and to finish them all as well as I could; then to select, by trial, the best of them, which I preserved; the rest were put by to be repolished. In this manner I made not less than 200, 7 feet;—150, 10 feet;—and about 80, 20 feet mirrors: not to mention those of the GREGORIAN form, or of the construction of Dr. SMITH's reflecting microscope, of which I also made a great number.

"My mechanical amusements went hand in hand with the optical ones. The number of stands I invented for these telescopes it would not be easy to assign. I contrived and delineated them of different forms, and executed the most promising of the designs. To these labours we owe my 7 feet NEWTONIAN TELESCOPE STAND, which was brought to its present convenient construction about 17 years

ago."—From Dr. HERSCHEL's Paper in the *Phil. Trans.* for 1795, vol. lxxxv. pp. 347—8.

"In the year 1783, I finished a very good 20 feet reflector, with a large aperture, and mounted it upon the plan of my present telescope."

Dr. H.'s Small 20 feet, I believe, had a 12 inch speculum — his Large 20 feet, one of 18½ inches in diameter.—W. K.

SIR WM. HERSCHEL'S CATALOGUES OF DOUBLE STARS

have opened a new, an interesting, and extensive source of research and contemplation for Astronomers, and may probably lead to the discovery of the motion of our System through infinite space.

Those who wish to examine these Stars, will find them more readily by the use of *Cary's* twelve or twenty-one inch celestial Globe, (on which is laid down the whole of the Double Stars, Clusters of stars, Nebulas, &c. contained in the Astronomical Catalogues of the *Rev. Mr. Wollaston*, compiled from the authorities of *Flamstead, De la Caille, Hevelius, Mayer, Bradley, Herschel, and Maskelyne*,) than by the aid of any Astronomical Atlas, &c. or other helps of that sort. These are sold at Mr. Cary's, Optician, near Norfolk Street, Strand.

Many of these beautiful and minute objects are visible in Telescopes, which are convenient to use and easy to obtain; a ridiculous *Vulgar Error* has somehow or other obtained, that they can only by

discovered with unwieldy Instruments of immense magnitude, and expense—which, instead of acting as a stimulus to Astronomical pursuits, has had a very contrary effect, and operated as a sedative to further inquiry.

*See Observations of the apparent Distances and Positions of* 380 *Double and Triple Stars, by* J. F. W. HERSCHEL, ESQ., M. A. F.R.S., &c., AND JAMES SOUTH, &c. F.R.S., &c., *in the Phil. Trans. for* 1825, *made with a* 5 *feet and a* 7 *feet Equatorial.*

"The excellent Object-glass for the FIVE FEET Telescope is 3¾ inches aperture, was made by the late P. and J. DOLLOND. The power ordinarily employed is 133; besides which, powers of 68, 116, 240, 303, and 381, were occasionally used, being double eye-pieces; and in some few cases a single lens, with a power of 578, was employed for the purpose of minute scrutiny. The extent of the field with these powers (in their order, beginning with the lowest, 68',) was respectively 34', 31', 20', 19' 19', 11', and ."—p. 11.

"The Object-glass of the SEVEN FEET Equatorial, is the work of MR. TULLEY, and may perhaps be regarded at present as the chef-d'œuvre of that eminent artist. It is five inches in clear aperture, and in distinctness, under high Magnifying powers, is probably excelled by no refractor existing. Proof of this will be found in the separation and measure-

ment of the most minute double stars, such as σ and η *Coronæ Borealis*, in its sharp definition of the double ring of Saturn, and various others of the most delicate celestial objects."

"Under favourable circumstances, with a power of 600, the disks of the two stars of η *Coronæ*, and of σ *Coronæ*; of ξ *Bootis*, and ξ *Orionis*, are shewn perfectly round, and as sharply defined as possible."—p. 12.

In No. 26 of the *Journal of Science*, of the Royal Institution, 8vo. 1822—in page 386, the reader will find some Astronomical Observations, and 24 Diagrams of Double Stars, laid down from Observations made by Mr. J. SOUTH, F.R.S., with an Achromatic Object-glass, made by Mr. TULLEY, of 3¼ inches aperture, having Three Convex Surfaces, and 45 inches focal length, of which Mr. S. says—

"An Object-glass, 3¼ inches in diameter, and of 45 inches focal length, having been made for me by TULLEY, from formulæ given by Mr. HERSCHEL, in a paper published in the *Phil. Trans.* for 1821, it became a matter of much interest to ascertain what merit it might possess; and for this purpose it was directed to some of those Double Stars, in which proximity or faintness renders one of them difficult to be seen, and the accompanying diagrams, Plate V. are faithful representations of the results; what, therefore, Mr. Herschel's *theory** told him would be good, Mr. TULLEY's *practice* has declared so. The

* See note at the foot of page 203.

magnifying power employed upon the stars was about 300."

## SIR WM. HERSCHEL'S

OBSERVATIONS ON DOUBLE STARS, COLLECTED AND ABRIDGED FROM THE VARIOUS VOLUMES OF THE PHIL. TRANS.; COMPRISING ALL HIS PRACTICAL REMARKS ON THOSE OBJECTS, WHICH ARE UNDERSTANDABLE BY PERSONS WHO HAVE NOT MADE OPTICS AND ASTRONOMY THEIR PARTICULAR STUDY.

By the method adopted—taking *the entire passages in the very words of the Author,* any possible danger of Misrepresenting the genuine sense of his text is entirely avoided; which would have been extremely difficult in the common mode of Abridgment, and much interesting information is now brought into one view, which heretofore could only be found dispersed through many expensive Volumes—which, it is hoped, will be as acceptable to the Reader, as the similar abridgment I have given of Sir Wm. H.'s Observations on SATURN.—W. K.

*The First* Catalogue of Double Stars. By Mr. Herschel, F.R.S. from* p. 112 *of* vol. lxxii. *of Phil. Trans.*

"*Introductory Remarks.*—The following catalogue

* Of this Catalogue, Dr. H. observes, "The above catalogue contains 269 double stars, 227 of which, to my present knowledge, have not been noticed by any person."

contains not only double stars, but also those that are treble, double-double, quadruple, double-treble, and multiple. The particulars I have given of them are comprehended under the following general heads; 1. The names of the stars and number in Flamstead's catalogue; or, if not contained there, such a description of their situation as will be found sufficient to point them out. 2. The comparative size of the stars. On this occasion I have used the terms equal, a little unequal, pretty unequal, considerably unequal, very unequal, extremely unequal, and excessively unequal, as expressing the different gradations to which I have endeavoured to affix always the same meaning. 3. The colours of the stars as they appeared to me when I viewed them. Here I must remark, that different eyes may perhaps differ a little in their estimations. I have, for instance, found, that the little star which is near $\alpha$ Herculis, by some to whom I have shewed it has been called green, and by others blue. Nor will this appear extraordinary when we recollect, that there are blues and greens which are very often, particularly by candle-light, mistaken for each other. The situation will also affect the colour a little, making a white star appear pale red, when the altitude is not sufficient to clear it of the vapours. It is difficult to find a criterion of the colours of stars, though I might in general observe, that Aldebaran appears red, Lyra white, and so on; but when I call the stars garnet, red, pale red, pale rose-colour, white

inclining to red, white inclining to blue, bluish white, blue, greenish, green, dusky, I wish rather to refer to the double stars themselves, to explain what is meant by those terms.

4. The distances of the stars are given several different ways. Those that are estimated by the diameter can hardly be liable to an error of so much as one quarter of a second; but here must be remembered, what I have before remarked on the comparative appearance of the diameter of stars in different instruments. Those that are measured by the micrometer, I fear, may be liable to an error of almost a whole second; and if not measured with the utmost care, to near 2″. This is, however, to be understood only of single measures; for the distance of many of them that have been measured very often in the course of 2 years' observations, can hardly differ so much as half a second from truth, when a proper mean of all the measures is taken. As I always make the wires of my micrometer outward tangents to the apparent diameter of the stars, all the measures must be understood to include both their diameters; so that we are to deduct the 2 semi-diameters of the stars, if we would have the distance of their centres. What I have said concerns only the wire micrometers, for my last new micrometer is of such a construction, that it immediately gives the distance of the centres; and its measures, as far as in a few months I have been able to find

out, may be relied on to about $\frac{1}{10}$th of a second, when a mean of three observations is taken. When I have added inaccurate, we may suspect an error of 3 or 4″. Exactly estimated may be taken to be true to about $\frac{1}{8}$th part of the whole distance; but only estimated, or about, &c. is in some respect quite undetermined; for *it* is hardly to be conceived how little we are able to judge of distances, when, by constantly changing the powers of the instrument, we are as it were left without any guide at all. I should not forget to add, that the measure of stars, when one is extremely small, must claim a greater indulgence than the rest, on account of the difficulty of seeing the wires when the field of view cannot be sufficiently enlightened.

5. The angle of position of the stars I have only given with regard to the parallel of declination, to be reduced to that with the ecliptic as occasion may require. The measures always suppose the large star to be the standard, and the situation of the small one is described accordingly. Thus, in Fig. 12, AF represents the apparent diurnal motion of a star in the direction of the parallel of declination AB; and the small star is said to be south preceding at *mn*, north preceding at *op*, south following at *qr*, and north following at *st*. The measure of these angles, I believe, may be relied on to 2°, or at most 3°, except when mentioned inaccurate, where an error amounting to 5° may possibly take place. In

many estimations of the angle without any wires at all, an error may amount to at least 10°, when the Stars are near to each other.

6. The dates, when I first perceived the stars to be double-treble, &c. are marked in the margin of each star. To shorten the work as much as possible, I have put L. for the *Large*, S. for the small star; W. for white; R. for red; D. for dusky; N. for north; S. for south.

*Introductory Remarks to Dr. Herschel's Second Catalogue of* 434 *more Double Stars, Phil. Trans.* vol. lxxv. p. 40.

"The observer should be furnished with Flamstead's Atlas Cœlestis, which must have the stars marked from the author's catalogue, by a number easily added to every star with pen and ink, as I have done to mine. The catalogue should also be numbered by an additional column, after that which contains the magnitudes.

"I hope, in some future editions of the Atlas, to see this method adopted in print, as the advantage of it is very considerable, both in referring to the catalogue for the place of a star laid down in the Atlas, and in finding a star in the latter, whose place is given in the former.

"I would recommend a precaution to those who

wish to examine the closest of my double stars. It relates to the adjustment of the focus. Supposing the telescope and the observer long enough out in the open air to have acquired a settled temperature, and the night sufficiently clear for the purpose; let the focus of the instrument be re-adjusted with the utmost delicacy upon a star known to be single, of nearly the same altitude, magnitude, and colour, as the star which is to be examined, or upon one star above, and another below, the same. Let the phenomena of the adjusting star be well attended to: as, whether it be perfectly round and well-defined, or affected with little appendages that frequently keep playing about the image of the star, undergoing small alterations while it passes through the field, at other times remaining fixed to it during the whole passage.

"Such deceptions may be detected by turning, or unscrewing, the Object-glass or speculum a little in its cell, when these appendages will be observed to revolve the same way.

"Being thus acquainted with the imperfections as well as perfections of the instrument, and going immediately from the adjusting star, which for that reason also should be as near as may be to the double star which is to be examined, we may hope to be successful.

"The astronomical Mr. Aubert, who did me the

honour to follow this method with $\gamma$ *Leonis*, which he did not find to be double when the telescope was adjusted by $\gamma$ itself, soon perceived the small star, after he had adjusted it upon Regulus.

"The instrument, being one of Mr. Dollond's best 3½ feet Achromatics*, shewed Mr. Aubert the

* There is no difficulty in accounting for Mr. Aubert's three and a half feet Achromatic shewing the two stars of $\gamma$ *Leonis* in close conjunction, or rather one partly hid behind the other; for be it remembered, until Dr. Herschel published his Catalogues of Double Stars, Astronomers confined their observations to the Moon and the Planets; and Telescopes were not finished and adjusted with that nicety that they must be for defining Double Stars neatly—which, if any old Telescope shews well, it is entirely from its *accidental* perfection.

The Telescope here alluded to was the 46 Inch Achromatic, with a triple Object-glass of $3\frac{6}{10}$ths diameter, which was the favourite Working Telescope of Mr. Aubert; I was surprised at this account of its non-performance, and had the curiosity to purchase this instrument of *Mr. Hodgson*, (who bought it at *Mr. Aubert's* sale,) in order to ascertain what its powers really were—as Mr. A. had *Four Telescopes* of this size, and this was his favourite, and produced on all occasions as the Champion of Achromatics, I thought that either Mr. A. or Dr. H. must be strangely deceived in their opinion of it.

The following is my observation with this Instrument on March the 10th, 1823: "With 162, that $\gamma$ Leonis was a Double Star, was evident to myself, and to a person not much accustomed to use a Telescope, who, without any hint from me, said, 'Is not it a Double Star?'"

Conceiving the Object-glass might have got out of Adjustment,

two stars $\gamma$ *Leonis* in very close conjunction, or rather one partly hid behind the other.

"On comparing these appearances with my observations of that double star, we must not be surprised to find that I place them at a visible distance from each other: for the Newtonian Reflectors, on the plan of my 7 feet one, as I have found, will give a much smaller image of the stars than the $3\frac{1}{2}$ feet Achromatic refractors; wherefore, the two stars, which, in refractors, as it were, run into each other, will in the reflector remain separate.

"For this reason also, those who only use such refractors must not be disappointed if they cannot perceive the 26, 30, 31, 36, 41, 44, 46, 47, 60, 75, 82, 86, and 87 stars of my first class to be double.

"All the observations in the following catalogue, on the relative magnitude, colour, and position of the stars, are to be understood as having been made with a 7 feet Newtonian, of $6\frac{3}{10}$ths inches aperture, with a power of 460, unless they are marked otherwise. This will account for the difference which observers may find in the relative magnitude; for should they use only a power of about 200, many of the small stars that are said to be very unequal,

I sent it to Mr. Dollond, who re-adjusted it; and I have spoken of its performance in my Observations on Double Stars It is right to remark, that the Two Stars of $\gamma$ *Leonis* are considerably more separate now, than they were when Sir W. H. made hte above observations.

must appear to them perhaps a degree lower in the scale, and become extremely and excessively unequal; and this will happen, though the quantity of light should be the very same which the Reflector has that served me to settle these particulars. I need not say, that on other accounts, such as a real difference in the light of the telescope, the presence of the moon, twilights, aurora borealis, or other causes, many of the small stars may be found to be of a different comparative lustre from what is assigned to them in the catalogue.

"The small star near Rigel, for instance, appears of a beautiful pale red colour, full, round, and well defined, with my 20 feet Reflector; the 10 feet instrument shews it also very well in fine evenings; the 7 feet requires more attention, nor is the small star defined, but of a dusky pale red colour. A good 3½ feet Achromatic of a large aperture, when *Rigel* is on the meridian, may, perhaps, also shew the small star, although I have not been able to see it with a very good instrument of that sort, which shews the small star that accompanies the *Pole Star*; but the evening was not very favourable.

"The measures of the distances were all taken with a parallel silk-worm's thread micrometer, and a power of 227 only. They are not, as in the former catalogue, with the diameters included, but from the centre of one star to the centre of the other."—See *Phil. Trans. for* 1785, vol. lxxv. p. 46.

"As soon as I was fully satisfied, that in the investigation of PARALLAX, the method of DOUBLE STARS would have many advantages above any other, it became necessary to look out for proper Stars. This introduced a new series of observations. I resolved to examine every star in the Heavens with the utmost attention, and a very high power, that I might collect such materials for this research as would enable me to fix my observations on those that would best answer my end; and I cannot help inviting every lover of Astronomy to join with me in Observations that must inevitably lead to new discoveries.

"Chuse stars that may be viewed sufficiently high to be clear of the vapours that swim near the horizon, when consequently we can employ the greatest powers our instruments are capable of. From experience I can also affirm, that the stars will bear a much higher degree of magnifying than other celestial objects. Too much has hitherto been taken for granted in optics: every natural philosopher is ready enough to allow the necessity of making experiments, and tracing out the steps of Nature; why this method should not be more pursued in the art of seeing does not appear. Theories are only to be used when proper data are assigned; but the data are carefully to be re-examined, when new improvements may widely alter the result of former experiments. Thus, we are told, that we can gain nothing by magnifying too much. I grant it; but shall never

believe I magnify too much, till by experience I find, that I can see better with a lower power. Nor is even that sufficient: a lower power may shew more of the object; it may shew it brighter, nay, even distincter, and therefore on the whole better; and yet the greater power may, in a particular case, be preferable: for if the object is so small as not to be at all visible with the lower power, and I can, by magnifying more, obtain a view of it, though neither so bright nor distinct as I could wish, is it not evident, that here this power is preferable to the former?

"The naturalist does not think himself obliged to account for all the phenomena he may observe; the astronomer and optician may claim the same privilege. When we increase the power, we lessen the light in the inverse ratio of the square of the power; and telescopes will, in general, discover more small stars, the more light they collect; yet with a power of 227 I cannot see the small star, near the star following *o* Aquilæ, when, by the same Telescope, it appears very plainly with the power of 460: now, in the latter case, the power being more than double, the light is less than the fourth part of the former. In such particular cases I generally suspect my own eyes, and have recourse to those of my friends. I had the pleasure of shewing this star to Dr. Watson, junior, who soon discovered the small star, which accompanies the other, with the power of 460; but

saw nothing of it with 227, though the place where to look for it had been pointed out to him by the higher power*. The experiment has been too often repeated to be doubtful, and has also been confirmed by others of nearly the same nature: for instance, the smallest of the two that accompany the star near *k* Aquilæ, the small star near *μ* Herculis, and the small star near *α* Lyræ, are invisible with my power of 227, but visible with the same aperture when the power is 460. (See the *Obs.* on *Double Stars*, in the preceding work.) Also the small stars near Flamstead's 24th of Aquila, the smaller of 2 near *δ* Coronæ, the small star near the star south of *ε* Aquilæ, the small star near the second *ο* Persei, the small star near the star which accompanies

* The Small Star, near the Pole Star, is easily visible in my 5 feet Achromatic, with from 44 to 1300—and as well with 100 as with any power.—W. K.

See *Pole Star, Double.*

See an Account of some Observations made to ascertain, whether MAGNIFYING POWER, or APERTURE, contributes most to the discerning of Small Stars in the Day, by the Rev. H. USHER, D.D. p. 37 of vol. ii. of the *Transactions of the Royal Irish Academy*.

"Small Stars were more easily visible in the 6 feet Achromatic, with an Aperture of 4$\frac{3}{10}$ths, with a power of 600, than with 200."

I cannot see the Small Star, near *α* Lyræ, in my 5 feet Achromatic, with 250—but it is easily visible with 350 and 450.—W. K.

Flamstead's 10th sub pede et scapula dextra Tauri, the small star near β Delphini, and *the small star near the Pole Star*, are all much brighter and stronger, and therefore much sooner seen with 460, than with 227.

"Great power may also, in particular circumstances, be favourable, even with an excess of aberration. When two stars are so close together as to make the scale for measuring the distance of their centres too small, if, by magnifying much, we can enlarge that distance, we may gain a considerable advantage, provided the centres, or apparent bodies of the stars, remain distinct enough for the purpose of these measures. The appearance of α Lyræ, in my 7 feet Newtonian Reflector, with a power of 460, is represented in fig. 1; with 2010, in fig. 2; with 3168, in fig. 3; and with 6450, in fig. 4. (See p. 400.) Now, in all these figures, we see that the centres are still distinct enough to measure their distances with sufficient truth; or, if any little error should be introduced by the magnitude of the central point, it will be more than sufficiently balanced by the largeness of the scale. In this manner, with a power of 3168, I have obtained a scale of no less than 10 6 ths inches for the distance of the centres of the two stars of α Geminorum; and as we know these centres to be but a few seconds distant, it is plain how great an advantage we gain by such an enlarged scale.

"These experiments have but very lately pointed

out to me a method of making a new micrometer, on a construction entirely different from any that are now in use, which I have been successful enough to put in practice, and by which I have already begun to determine the distance of the centres of some of the most remarkable double stars to a very great degree of accuracy.

"The powers that may be used on various double stars are different, according to their relative magnitudes: ε Bootis, for instance, will not bear the same power as α Geminorum, nor would it be difficult to assign a reason for it; but as I here shall merely confine myself to facts, it will be sufficient in general to mention, that two stars, which are equal, or nearly so, will bear a very high power: with α Geminorum I have gone as far as 3168; but with the former only to 2010.

"*The difficulty of using high powers* is exceedingly great; for the field of view takes in less than the diameter of the hair or wire in the finder, and the effect of the earth's diurnal motion is so great, that it requires a great deal of practice to find the object, and manage the instrument. It appears to me very probable, that the diurnal motion of the earth will be the greatest obstacle to our progress in magnifying, unless we can introduce a proper mechanism to carry our telescopes in a contrary motion.

"Though opticians have proved that 2 Eye-glasses will give a more correct image than one, I

have always, from experience, persisted in refusing the assistance of a 2d glass, which is sure to introduce errors greater than those we would correct. Let us resign the double Eye-glass to those who view objects merely for entertainment, and must have an exorbitant field of view. To a philosopher this is an unpardonable indulgence. I have tried both the single and double Eye-glass of equal powers, and always found that *the Single Eye-glass had much the superiority in point of light and distinctness.* With the double* Eye-glass I could not see the belts on Saturn, which I very plainly saw with the single one. I would, however, except all those cases where a large field is absolutely necessary, and where power joined to distinctness is not the sole object of our view.

" The application of the different powers of a telescope in general is of some consequence; and, in answer to those who may think I have strained or overcharged mine, I must observe, that a single glance at the subsequent *h* Draconis, $\eta$ Coronæ, and the star near $\mu$ Bootis, with a power of 460, shewed them to me as double stars; when, in 2 former reviews of the Heavens, I had twice set them down in

* If the only advantage be the trifling increase of Illuminating power, that may be obtained by increasing the Aperture of the Telescope.—See the Author's *Obs. on Saturn,* and *Chapter on Galilean Telescopes,* and *on Single Concave and Convex Lenses.*

my journal as single stars, where I used only the power of 222 and 227, and in all probability should never have found them double, had I not looked with a higher power.

"We are to remember, that it is much easier to see an object when it is pointed out to us, than when it falls in our way unexpectedly, especially if of such a nature as to require some attention to be seen at all; but to say no more of other advantages of high powers, it is evident, that in the research of the parallax of the fixed stars they are absolutely necessary. If we would distinctly perceive and measure, or estimate extremely small quantities, such as a 10th of a second, it appears, that when we use a power of 460, this 10th of a second will be no more in appearance than 46″, and even with a power of 1500 will be but 2′ 30″, which is a quantity not much more than sufficient to judge well of objects, and distinguish them from each other, such as a circle from a square, triangle, or polygon*.

"It has been observed, that objects become indistinct when the principal optic† pencil at the eye

* "By a set of experiments, made in the year 1774, I found, that I could discover or perceive a bright object, such as white paper, against the sky-light, when it subtended an angle of 35″; but could only distinguish it to be a circle, and no other figure, when it appeared under an angle of 2′ 24″."

† This has been said—and truly, of the Objects it has been

becomes less than the 40th or 50th part of an inch in diameter.

"In the experiments that have been made on this subject, it appears to me, that the indistinctness which is ascribed to the smallness of the optical pencil may be owing to very different causes: at least it will be easy to bring contrary experiments of extremely small pencils, not at all affected by this inconvenience; for instance, it is well known, that microscopes, consisting of a single lens or globule, are remarkable for distinctness. We also know that they have been made so small, as to magnify above 10,000 times*. From this we may infer that their apertures, and consequently the diameters of the optic pencil at the eye, could not exceed the 2500th part of an inch. I am, therefore, inclined to believe, that we must look for distinctness in the perfection of the Object-speculum or Object-glass of a Telescope; and if we can make the first image in the focus of a speculum almost as perfect as the real object, what should hinder our magnifying but the want of light†? Now, if the object has light suf-

said of—*i. e.*—a Printed Bill—and the Planets—which are seldom so well defined, with a greater power than is given by reducing the Diameter of an Object-metal into 10ths of inches, and multiplying that by 3 or 4.—W. K.

* "See Padre Della Torre's *Method*, &c. Scelta di Opuscoli."

† *Want of Light* is not the Greatest obstacle to the increase of

ficient, as the stars most undoubtedly have, I see no reason why we should limit the powers of our instruments by any theory. Is it not best to have recourse to experiments to find how far our endeavours to render the first image perfect, have been successful?

"If I should mention, in my list of observations, a few Double Stars that may be found difficult to be verified by other Telescopes, I must beg the indulgence of the observers. I hope it will sufficiently appear, that I have guarded against optical delusions; and every astronomer, I make no doubt, will find, by those observations that fall within the compass of his instruments, and attention to circumstances necessary to the right management of them, that I have had all along truth and reality in view,

Magnifying Power beyond a certain degree — the great and irremediable impediment is the Atmosphere of the Earth—Speculums, Dr. H. informs us, have been worked perfectly good of 10 inches in Diameter, and the magnifying power given by multiplying their Diameter by 40—*i. e.* 400 times, is the maximum that can be managed.

With *a Double Eye-tube* of the usual construction, magnifying 350, *Spica Virginis*, when on the Meridian, passed the field of my 5 feet Achromatic in 28 seconds—in the Double Eye-piece, the Vision was distinct almost to quite the edge of the field—with the *Single Lens*, except in the centre—forming at most not more than one-third of the field, it was too distorted to be of any use: so to keep it in the distinct part of the Field of view of a single Eye-glass, the Instrument must be kept in almost perpetual motion.—W. K.

as the sole object of my endeavours; and therefore, he will be inclined to give some credit to what he does not immediately perceive, when he finds himself successful where he takes the proper precautions so necessary in delicate observations, even with the best instruments. I have been in some doubt in what manner to communicate these observations. My first view was to have methodised them properly; but I find them so extensive, that there is but little probability that one person should be able to bring them to a conclusion, for which reason I have now resolved to give them, unfinished as they are, that every person who is inclined to engage in this pursuit may become a fellow-labourer.

" In settling the distances of double stars, I have occasionally used 2 different ways. Those that are extremely near each other may be estimated by the eye, in measures of their own apparent diameters. For this purpose their distance should not much exceed 2 diameters of the larger, as the eye cannot so well make a good estimation when the interval between them is greater. This method has often the preference to that of the micrometer: for instance, when the diameter of a small star, perhaps not equal to half a second, is double the vacancy between the two stars. Here a micrometer ought to measure 10ths of seconds at least, otherwise we could not, with any degree of confidence, rely on its measures; nay, even then, if the stars are situated in the same

parallel of declination, and near the equator, their quick motion across the micrometer makes it extremely difficult to measure them, and in that case an estimation by the eye is preferable to any other measure; but this requires not a little practice, precaution, and time, and yet with proper care it will be found that this method is capable of great exactness. Let 2 small circles be drawn, either equal or unequal, at a distance not exceeding twice the diameter of the larger: let these be shewn to several persons in the same light and point of view. Then, if every one of them will separately and carefully write down his estimation of the interval between them, in the proportion of either of their diameters, it will be found on a comparison, that there will seldom be so much as a quarter of a diameter difference among all the estimations. If this agreement takes place with so many different eyes, much more may we expect it in the estimations of the same eye, when accustomed to this kind of judgment.

"I have divided the double stars into several different classes. In the first, I have placed all those which require indeed a very superior telescope, the utmost clearness of air, and every other favourable circumstance to be seen at all, or well enough to judge of them. They seemed to me on that account to deserve a separate place, that an observer might not condemn his instrument or his eye, if he should not be successful in distinguishing them. As these

are some of the finest, most minute, and most delicate objects of vision I ever beheld, I shall be happy to hear that my observations have been verified by other persons, which I make no doubt the curious in astronomy will soon undertake. I should observe, that since it will require no common stretch of power and distinctness to see these double stars, it will, therefore, not be amiss to go gradually through a few preparatory steps of vision, such as the following: when η Coronæ Borealis, one of the most minute double stars, is proposed to be viewed, let the telescope be some time before directed to α Geminorum; or, if not in view, to either of the following stars, ζ Aquarii, μ Draconis, ρ Herculis, α Piscium, or the curious double-double star ε Lyræ. These should be kept in view for a considerable time, that the eye may acquire the habit of seeing such objects well and distinctly. The observer may next proceed to ξ Ursæ majoris, and the beautiful treble star in Monoceros's right fore-foot; after these to ι Bootis, which is a fine miniature of α Geminorum, to the star preceding α Orionis, and to n Orionis. By this time both the eye and the telescope will be prepared for a still finer picture, which is η Coronæ Borealis. It will be in vain to attempt this latter, if all the former, at least ι Bootis cannot be distinctly perceived to be fairly separated, because it is almost as fine a miniature of ι Bootis as that is of α Geminorum. If the observer has been successful in all

these, he may then, at the same time, try *h* Draconis, though I question whether any power less than 4 or 500 will shew it to be double; but all the former I have seen very well with 227.

" To try the stars of unequal magnitudes, it will be expedient to take them in some such order as the following: α Herculis, ω Aurigæ, δ Geminorum, *k* Cygni, ε Persei, and *b* Draconis; from these the observer may proceed to a most beautiful object, ε Bootis, which I have closely attended these 2 years, as very proper for the investigation of the parallax of the fixed stars.

" It appears, from what has been said, that these *Double stars are a most excellent way of trying a Telescope;* and as the foregoing remarks have suggested the method of seeing how far the power and distinctness of our instruments will reach, I shall add the way of finding how much light we have The observer may begin with the Pole Star and α Lyræ; then go to the star south of ε Aquilæ, the treble star near *k* Aquilæ, and last of all to the star following *o* Aquilæ. Now, if his telescope has not a great deal of good distinct light, he will not be able to see some of the small stars that accompany them.

" In the 2d class of double stars, I have put all those that are proper for estimations by the eye, or very delicate measures of the micrometer. To compare the distances with the apparent diameters, the

power of the telescope should not be much less than 200, as they will otherwise be too close for the purpose. The instrument ought also to be as much as possible free from rays that surround a star in common telescopes, and should give the apparent diameters of a double star perfectly round and well-defined, with a deep black division between them, as in fig. 6, which represents α Geminorum as I have often seen it, in my 7 feet Newtonian, with a power of 460. It will be necessary here to take notice, that the estimations made with one telescope cannot be applied to those made with another; nor can the estimations made with different powers, though with the same telescope, be applied to each other. Whatever may be the cause of the apparent diameters of the stars, they are certainly not of equal magnitude with the same powers in different telescopes, nor of proportional magnitude with different powers in the same telescope. In my instruments, I have ever found less diameter in proportion the higher I was able to go in power, and never have I found so small a proportional diameter as when I magnified 6450 times*; therefore, if we would wish to compare any

* "See the measures of the diameter of α Lyræ†. Catalogue of Double Stars, 5th class."—Orig.

---

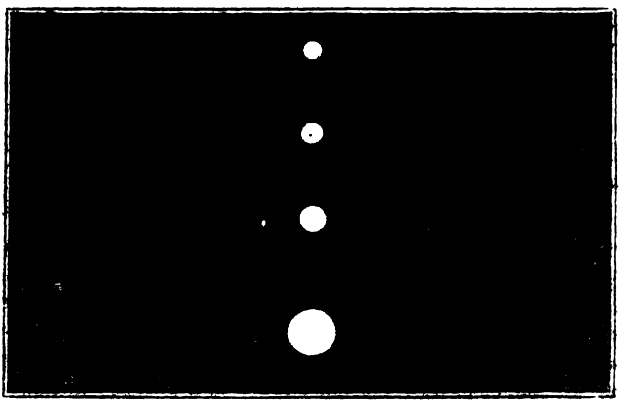
† With 460, the diameter of α Lyræ is $\frac{1}{10}$th of an inch. With 2010, $\frac{1}{8}$th of an inch.

such observations together, with a view to see whether a change in the distance has taken place,

With 3168, $\frac{1}{8}$th and $\frac{1}{6}$th of an 8th.,
With 6450, $\frac{1}{4}$th of an inch.

The accompanying Diagrams shew the Diameters of the Stars as given by Sir W. H.—only the aberrations which are drawn around them by Sir Wm. are omitted here on account of the space which they would occupy.

*Sir William Herschel's Diagrams of the diameter of α Lyræ, as it appeared in his 7 feet Newtonian, with an aperture of* 6$\frac{3}{10}$*ths inches; the upper figure as seen with a power of* 460, *the second with* 2010, *the third with* 3168, *and the fourth with* 6450.



In Sir Wm. H.'s diagram of *Castor*, which was made with a Newtonian Telescope of 7 feet focus, 6¼th Aperture, and power of 460.—See vol. lxxii. of the *Phil. Trans.*—the *Larger* Star is the twelfth of an inch in diameter—the *Smaller* Star the sixteenth,

it should be done with the very same telescope and power, even with the very same eye-glass or glasses; for others, though of equal power and goodness, would most probably give different proportional diameters of the stars.

"In the 3d class I have placed all those double stars that are more than 5 but less than 15″ asunder: and for that reason, if they should be used for observations on the parallax of the fixed stars, they ought to be considered as quite free from the effects of refraction, &c. In the same manner that the stars in the 1st and 2d classes will serve to try the goodness of the most capital instruments, these will afford objects for telescopes of inferior power, such as magnify from 40 to 100 times. The observer may

and the separation between them one-tenth and one half-tenth of an inch.—For a particular account of *Castor*, see the Chapter on *Double Stars*.

In Mr. J. SOUTH's diagram of *Castor*, in No. xxvi. of the *Journal of Science*, edited at the Royal Institution, which was drawn with an Achromatic Object-glass, made by Mr. Tulley, of 3¾th inches aperture, having Three convex surfaces, 45 inches focal length, and Magnifying, he states, about 300 times—the *Larger Star* is the 30th of an Inch in diameter, and *the Smaller Star* the 50th of an Inch, and *the distance* between them the 35th of an Inch.

If you wish to estimate the apparent Diameters of Stars—make a dozen dots on a paper—from the 8th to the 10th of an inch in diameter—this will assist your Eye in its measurement very much.—W. K.

take them in this or the like order: ζ Ursæ majoris, γ Delphini, γ Arietis, π Bootis, γ Virginis, ι Cassiopeæ, μ Cygni. And if he can see all these, he may pass over into the 2d class, and direct his instrument to some of those that were pointed out as objects for the very best telescopes, where I suppose he will soon find the want of superior power.

"The 4th, 5th, and 6th classes, contain double stars that are from 15″ to 30″, from 30″ to 1′, and from 1′ to 2′ or more asunder."—From Dr. HERSCHEL's Paper *on the Parallax of the fixed Stars*, in the *Phil. Trans. for* 1782, vol. lxxii. p. 91, &c.

---

*Account of some Observations tending to investigate the Construction of the Heavens, by* Dr. HERSCHEL, *in Phil. Trans.* vol. lxxiv. p. 437, *made "with a Telescope of the Newtonian Form, with an Object-Speculum of* 20 *feet focal length—and its Aperture* 18$\frac{7}{10}$*ths inches."*

"IT may be expected, that the great advantage of a large aperture would be most sensibly perceived with all those objects that require much light, such as the very small and immensely distant fixed stars, the very faint nebulæ, the close and compressed clusters of stars, and the remote planets.

"On applying the telescope to a part of the *Via*

*Lactea*, I found that it completely resolved the whole whitish appearance into small stars, which my former telescopes had not light enough to effect. The portion of this extensive tract, which it has hitherto been convenient for me to observe, is that immediately about the hand and club of Orion. The glorious multitude of stars, of all possible sizes, that presented themselves here to my view, was truly astonishing; but as the dazzling brightness of glittering stars may easily mislead us so far, as to estimate their number greater than it really is, I endeavoured to ascertain this point by counting many fields, and computing, from a mean of them, what a certain given portion of the milky way might contain. Among many trials of this sort, I found, last January the 18th, that six fields, promiscuously taken, contained 110, 60, 70, 90, 70, and 74 stars each. I then tried to pick out the most vacant place that was to be found in that neighbourhood, and counted 63 stars. A mean of the first six, gives 79 stars for each field. Hence, by allowing 15 minutes of a great circle for the diameter of my field of view, we gather, that a belt of 15 degrees long and 2 broad, or the quantity which I have often seen pass through the field of my telescope in one hour's time, could not well contain less than fifty thousand stars, that were large enough to be distinctly numbered. But, besides these, I suspected

at least twice as many more, which, for want of light, I could only see now and then by faint glittering and interrupted glimpses."—Vol. lxxiv. pp. 437 and 8.

"In the most crowded part of the Milky Way, I have had fields of view that contained no less than 588 stars—(see the Table of Gages, p. 235)—and these were continued for many minutes, so that *in one quarter of an hour's time there passed no less than* 116,000 *Stars through the field of view of my Telescope.*

"The breadth of my sweep was 2° 26′, to which must be added 15′ for two semi-diameters of the field. Then, putting $161 = a$, the number of fields in 15 minutes of time; $7854 = b$, the proportion of a circle to 1, its circumscribed square; $\varphi =$ sine of 74° 22′, the polar distance of the middle of the sweep reduced to the present time; and $588 = S$, the number of stars in a field of view, we have $\frac{a \varphi S}{b} = 116076$ stars."—Dr. HERSCHEL *on the Construction of the Heavens*, p. 213 of vol. lxxv. of the *Phil. Trans.* for 1785.

"The SMALL SWEEPER is a Newtonian Reflector, of 2 feet focal length; and, with an aperture of 42 inches, has only a Magnifying power of 24, and a field of view 2° 12′.

"Its distinctness is so perfect, that it will shew

letters at a moderate distance, with a magnifying power of 2000*; and its movements are so convenient, that the eye remains at rest while the instrument makes a sweep from the horizon to the zenith.

" A large one of the same construction, has an aperture of 92 inches, with a focal length of 5 feet 3 inches.

" It is also charged low enough for the eye to take in the whole Optic Pencil; and its Penetrating Power, with a double Eye-Glass, is $\sqrt{\frac{,41 \times 92^2 - 21^2}{2}} = 28,57$."—See Dr. HERSCHEL's Paper in page 71 of vol. xc. of *Phil. Trans.*

" To find THE DISTANCE OF THE FIXED STARS has been a problem which many eminent astronomers have attempted to solve; but about which, after all, we remain in a great measure still in the dark. Various methods have been pursued without success, and the result of the finest observations has hardly given us more than a distant approximation, from which we may conclude, that the nearest of the fixed stars cannot be less than 40 thousand diameters of the whole annual orbit of the earth distant from us. Trigonometry, by whose powerful assistance the mathematician has boldly ascended into the

* This would require an Eye-Glass of less than the 80th of an Inch focus.

planetary regions, and measured the diameters and orbits of the heavenly bodies, for want of a proper base, can here be but of little service; for the whole diameter of the annual orbit of the earth is a mere point when compared to the immense distance of the stars."—Dr. HERSCHEL, in *Phil. Trans.* for 1782, p. 82.

End of Sir W. H.'s Observations on Double Stars.

---

## INTRODUCTORY OBSERVATIONS ON DOUBLE STARS, BY DR. KITCHINER.

The Opinions of some of the Old Authors on the Fixed Stars are odd enough, and oddly enough expressed.—We give the following specimen.

"The fixed stars, when beheld with a Telescope, appear prodigiously small; and whereas *Tycho Brahe* tells us, that those of the first magnitude appear to the naked sight about two minutes diameter, they appear not unto us, according to *Galileo*, but five seconds diameter, which is twenty-four times less. *Tycho Brahe* makes these stars to be sixty or seventy times bigger than the earth; at this time, on the contrary, they are found to be 200 times less than the earth."

"Utrum horum mavis accipe."

"*Kepler* warns us, that with the telescope the

greatness of any fixed star cannot be determined, because by how much better the glass is, by so much the lesser the stars appear*, they are judged to be very far from being all of a bigness; those visible to the naked eye are taken to be of six several magnitudes: those of the first rate, are conceived one hundred and eight times bigger than the earth; such are *the bigger Dog Star,—the Bull's Eye*, &c.: those of the sixth and least rate only eighteen times bigger than it. But to come to a perfect and exact knowledge of the distance of the heavenly bodies (by miles or such known measures,) of their bigness, substance, frame, and contexture, is not to be expected; nor will any, except madmen, pretend to have made such discoveries. There are very few things, which truly wise men, will say they thoroughly understand, even amongst sublunary bodies. By this ingenious dealing, the reader will be able easily to gather what kind of belief he is to give to the foregoing calculations, or accounts of the distances and magnitudes of these bodies. They are mostly but the conjectures of men very learned, industrious, and knowing in this kind. But there is as great a difference betwixt the knowledge which artists and speculative men have of the heavens, stars, and orbs, and that

* A humourist, to whom I read the above quotation, replied, "Then in a Glass which is quite perfect, I suppose you cannot see any Stars at all!"

which the common people have, as there is betwixt the common people and brutes' notices of them."—

> 'Man differs more from man, than man from beast.'
>
> G. COLMAN, Jun.

Vide *Astronomy's Advancement*, or *News for the Curious, being a Treatise on Telescopes; a piece containing great Curiosities: done out of the French, by Joseph Walker, London*, 1684.

Some sublime Geniuses have talked of Immeasurable Space, and Distances only not Infinite, with an air of as much confidence, as a mail Coachman would tell you the distance between London and York.—Such is the kind of talk which I suppose an old Medical Author alluded to, when he wrote,—"Some have been *talked to Death*, which is the most agonistic and tedious way of Expiring."

An Arithmetician, who pretends to calculate exactly the Distance or the Dimension of a fixed Star, deserves about as much attention—as a Madman telling his dream; or as Sir Hudibras, when he reckoned that the Sun, and his brethren the STARS, were

> "——————a piece
> Of red hot iron as big as Greece"

And of the MOON tells,

> "What her diameter to an inch is,
> And proved she was not made of Cream Cheese."

"Trace Science, then, with Modesty thy guide:
First strip off all her equipage of Pride;
Deduct what is but vanity and dress,
Or learning's luxury or idleness;
Or tricks, to shew the stretch of human brain,
Mere curious pleasure, or ingenious pain:
Then see how little the remaining sum
Which served the past, and must the time to come."

POPE.

THE THREE VARIETIES OF DOUBLE STARS

are those which resemble,

1st, $\gamma$ *Andromeda*—the Smaller Star of a *Blue* colour.

2d, $\alpha$ *Geminorum*—nearly *Equal* in Size and colour.

3dly, *The Polar Star*—extremely *Unequal* in Size.

The Three Stars above mentioned may be seen in Telescopes of moderate magnitude, and will give you as good an idea of those which are more difficult to define, and are only visible in very perfect and very large Telescopes, as a Kitten does of a Cat:—for instance,

$\gamma$ *Andromeda*, in a 30 inch Achromatic, of 2 inches aperture, with 80, appears like $\varepsilon$ Bootis in a fine 5 feet, with an aperture of 3¾ths inches, and power of 460.

$\alpha$ *Geminorum*, in a Two feet Achromatic, with a power of 100, is like $\eta$ *Coronæ* in a 7 feet Achromatic, with 5 inches aperture, and power of 550—

(see Mr. TULLEY's account of it in page 296, where the power is misprinted 350, instead of 550.—(See Sir W. H.'s *Obs.* on this Star, in page 397.)—ε *Lyræ* in a good Achromatic Opera-glass which magnifies 5 times, appears like α *Geminorum.*

*The Pole Star*, in a 3½ feet Achromatic, of $2\frac{6}{10}$ths inches aperture, with 80, nearly resembles α *Lyræ* in my 5 feet, with 3¾ths inches aperture, with 450; only, with that power, the small Star near α *Lyræ* is fainter, and about double the distance from *Lyra*, than the Star which accompanies the Pole Star is with a power of 80.

The 1st and 2d Classes appear to me to be equally easily definable in Achromatic, Gregorian, and Newtonian Telescopes—and those of the 3d Class I have seen most easily in Achromatic and Newtonian Telescopes.

I have seldom seen the small Star near the Polar Star in a Gregorian with less than 5 inches aperture, and better with a triple Object-glass of $3\frac{6}{10}$ths inches diameter, than in several Gregorians of 7 inches diameter—the same Observation applies to the small Star near *Rigel.*

This failure of the *Gregorians*, I know now, was occasioned by their not having been finished and adjusted for observing Double Stars,—which, as I have before noticed, are the most severe tests of the defining power of a Telescope.

The following brief Accounts of DOUBLE STARS,

are offered as hints to those who are inexperienced in Telescopes, what objects they may expect to see in Instruments of various sizes and constructions, provided they are good of the kind.

No. 1. *γ Andromeda* is visible even in a 1 foot Achromatic Telescope, with 35; but the Blue colour of the Smaller of the Two Stars is not plainly remarkable with an Achromatic of less than Two, or a Gregorian of less than Three, inches aperture, and Magnifying power of at least 80.—See *Obs.* on *γ Andromeda*, at page 435.

No. 2. *α Geminorum* is another easy Object, and may be perceived to be two Stars with a 1 foot Achromatic, with 80—and seen distinctly separate, in a 2 feet, with 100.

No. 3. *ε Lyræ*—this quintuple Star, which to the naked Eye appears as a Single Star, is to be seen in an Achromatic Opera-glass, with a power of 5, or with a common finder with a power of 5 or 6 times, very distinctly as Two Stars.

No. 4. *α Herculis*—the small blue Star is discernible in a 30 inch, of 2 inches aperture; but is not well seen with less than 2$\frac{3}{4}$ths inches aperture.

No. 5. *γ Leonis* is visible in a 44 Inch Achromatic, with 2$\frac{3}{4}$ths aperture, with 180—and 270 shews it very well. I have seen this very well with 270, in a 30 inch Achromatic, with 2$\frac{3}{4}$ths inches aperture.—See page 443.

No. 6. *The Polar Star*—with any power higher than 40, in Achromatics of 2¾ths, or Reflecting Telescopes of 4½ inches aperture.—See page 446.

No. 7. *Rigel*—in a 3½ feet Achromatic, of 2¾ths aperture, or a Reflector of 4½ inches aperture—with any power between 80 and 130.—See page 451.

No. 8. ε *Bootis* is seldom distinctly defined, with an Achromatic of less aperture than 3¼th inches, or a Reflector of less than 5 inches, and a power of at least 250.—See page 450.

I have never SEEN* the Blue Star so perfectly and distinctly detached from the larger Star as I could wish, in less than a 46 inch Achromatic, with an aperture of $3\frac{6}{10}$ths inches, and a power of 350, and still better in a 5 feet, with an Aperture of $3\frac{8}{10}$ths, with 450—a higher power than that I have not thought any advantage.

No. 9. α *Lyræ*—in a 5 feet Achromatic Telescope, with 350 and 450.—See page 463.

The Novice must not always expect to see these extremely minute objects to the utmost advantage, as I have described them, as seen at favourable moments with fine Instruments—even when they are near to the Meridian, and the *Illuminating* power of the Telescope is in due proportion to the *Magni-*

* See what I mean by the word SEEING, in the 15th line of page 415.

*fying* power, and the Instrument is *Extremely* perfect—unless *the Air be very clear and calm, and every circumstance be favourable.*—See the 8 Goods requisite, in page 343.

Such is the capricious and ever-varying state of the Atmosphere of this Country, that many Evenings which seem to be extremely fine, and the Stars appear brilliant to the naked Eye, are quite unfit for Observation, and our best Telescopes will perform badly.—See Chapter XVIII. of *Hints for Choosing Telescopes* and *Observing Celestial Objects;* and Sir W. H.'s *Obs.* on the causes which prevent Telescopes from acting, in page 326 of this work.

The apparent Diameters, and the Distance of *Double Stars* from each other, vary very much,—according to the different states of the Atmosphere,—the Defining,—the Illuminating,—and the Magnifying power of the Telescope, and the proximity of the Stars to the Meridian.

The larger the aperture of the Telescope, and the more perfect it is, the larger appears the separation, and the deeper becomes the tone of the colour of Double Stars,—this is in fact no more than saying, that to see very faint and very small Objects well, You must have plenty of Light.—See Dr. Herschel's *Obs.* on *Castor,* $\gamma$ *Leonis,* $\varepsilon$ *Bootis,* and *Rigel* (p. 385), and after, my *Obs.* on those Stars.

Some small Stars require little Magnifying power

but a great deal of distinct light to be perfectly seen; such a one is that which accompanies *Rigel*, which is visible in a fine 5 feet Achromatic, or a 7 feet Newtonian, with a power of 100—and becomes invisible with 460. The small star near α *Lyræ* is of an opposite quality; it is not visible with less than 250, and better with 460.—See Sir W. H.'s *Obs.* thereon, in page 388.

To see each Double Star to the utmost advantage, you must apply to each a peculiar degree of Magnifying and Illuminating power, which I shall endeavour to state in the Observations on the 9 Double Stars, at the end of this Chapter.

*The Magnitude and Colour* of Celestial Objects* appear surprisingly different, to different Eyes.—The same Evening that, with a power of 180, the planet *Jupiter* has appeared to me to be about an Inch in diameter,—a person, who observed it the next minute, has said it looks as big as the Moon;—another, fancied it about Four inches in diameter;—and a third thought that it did not appear quite so large as a small Pea.

" It will be necessary here to take notice, that the estimations made with one Telescope, cannot be applied to those made with another. Whatever may be the cause of the apparent diameter of the

* See the Observations of α *Herculis*, and Sir WM. HERSCHEL'S Introductory Remarks to his First Catalogue of Double Stars.

Stars, they are certainly not of equal magnitude with the same powers in different Telescopes, nor of proportional magnitude with different powers in the same Telescope."—Sir Wm. Herschel, in vol. lxxii. of the *Phil. Trans.*—See *Obs.* on *Castor,* in the Chapter on *Double Stars.*

Very few Instruments are so perfect, that they will perform perfectly on All Double Stars. There is almost always, some false light flitting about some part of the Image of a Star; and if a small Star happens to be in that part, it is enveloped therein, and is

"Invisible or dimly seen."

See *Obs.* on ε *Bootis.*

I do not call it SEEING a Star Double, when you can only, now and then, merely imagine that you can *perceive* (with your mind's eye) a faint glimpse of a little flitting ghost of an accompanying Star, hopping and skipping about during fits of easy transmission—but only, when the apparent diameter of each of the Stars is perfectly defined—and as perfectly separate, and there is a deep black division between them, as they are delineated in Sir Wm. H.'s Diagram of Castor, in the Frontispiece to this work—and see Sir Wm. H.'s *Obs.* in page 399 of this Book.

The Reader must not expect that every Telescope which is fitted up for *Terrestrial* purposes,—will

properly carry for *Celestial* purposes extraordinary high Magnifying Powers,—nothing like it;—there are but few Superlative *Star* Telescopes.

To bear an uncommonly powerful Eye-glass for *Celestial* purposes, you must have an uncommonly perfect Object-glass, or Object-metal, and the difficulty of making this, increases as its Magnitude, and Magnifying power increases; and the Instrument must be adjusted at a Fixed Star, which is a much more elaborate and Eye-teazing operation than the ordinary test of the defining power of Day-Telescopes—*i. e.* a Printed Paper.

If I was an Optician,—I think that I would about as willingly *Waltz blindfold and barefoot among* 9 *Red-hot Ploughshares laid at unequal distances from each other,* as have all my Telescopes tried by that truly troublesome test, a Fixed Star.

The Planet *Jupiter* was, till within the last 30 years, considered the grand test of Telescopes for Celestial purposes, *and when it is near to the Meridian* it is a pretty severe one. I think that the Division in the Ring of *Saturn* is a severer criterion of defining power than the sharpness of the Disk of Jupiter; but many Glasses will define a Printed Paper, and shew the *Planets* pretty well, which will not so well define *Double Stars,*—and this merely because they were not adjusted at a Star.

*Double Stars* were not thought of till the attention of Astronomers was called to them, by *Sir William*

*Herschel* publishing his Catalogues in the *Phil. Trans.* for 1782 and 1785 — since that time, the Art of making all kinds of Telescopes has been gradually improving, and both the Optical and Mechanical parts of them, are now, made very much better than they were Thirty years ago.

When a Telescope is perfectly adjusted,—a very trifling accident will derange it so as to prevent its properly defining *a Star*, although it may not perceptibly affect the brightness or distinctness of the vision of it with any other object, not even with the Planet *Jupiter*.

Before You condemn a Telescope, because it does not very nicely define a Star,—try it several Evenings with several Eye-pieces, taking care that the Objects of your Observation are near to the Meridian — and let the maker of it (*trust it with no other Person*) examine whether it be in perfect Adjustment. — See Chapter XVIII. of *Hints for Choosing Telescopes and Observing Celestial Objects.*

*Defects* in *Eye-glasses* are seldom suspected—(see page 317)—but however perfect the original power of the Object-glass or Speculum may be, it will avail little, if one of your Eye-glasses is scratched, or veiny, &c., or not quite clean, or they are not exactly truly centred to each other, or to the Object-glass.— See 7 Rules for the construction of Eye-pieces, in

p. 212.—*Sir Wm. Herschel's* Observation in p. 31 of the 95th vol. of the *Phil. Trans.* is perfectly true:— " The best Eye-lens will give the least spurious diameter of a Star."

This is proved by Sir Wm. H.'s Observation of *α Geminorum* on the 8th April, 1778—(just Three days before I was born,) " with 222, the vacancy between the two Stars was a little more than 1 diameter of the larger Star; with 227, 1½ diameter."—See Sir Wm. H.'s Catalogue of Double Stars, in the 72d vol. of the *Phil. Trans.* p. 112, &c. The small addition of only 5 times in the Magnifying power, could not have produced so great a difference in the distances between these stars, without some other cause than the mere variation of the Magnifying Power.

*A Fixed Star of the first magnitude* is the best criterion of the degree of perfection of Telescopes; as, the least defect in the figure, or adjustment of the metals in a Reflector, or of the object-glass in a Refractor, is immediately seen; the Star not appearing round, but surrounded by false lights and little flitting luminous accompaniments; and when You are panting with the expectation of having the pleasure of seeing them *Bald and Clean Shaved*, they will present themselves in *Periwigs*, or, like a Beau of Twoscore Years ago, with Two Curls and a Twister.—See page 94.

The following very valuable and accurate observations of Dr. Herschel, I have copied from the second part of the *Phil. Trans.* for 1803, as they are highly interesting to all observers of Double Stars.

"From a number of observations and experiments I have made on the subject, it is certain that *the apparent Diameter of a Star*, in a reflecting telescope, depends chiefly upon the four following circumstances:—the aperture of the mirror with respect to its focal length; the distinctness of the mirror; the magnifying power; and the state of the atmosphere at the time of observation.

"By a contraction of the aperture, we can increase the apparent diameter of a star, so as to make it resemble a small planetary disk. If distinctness should be wanting, it is evident that the image of objects will not be sharp and well defined, and that they will consequently appear larger than they ought. The effect of *Magnifying power* is, to occasion a relative increase of the vacancy between two stars that are very near each other; but the ratio of the increase of the distance is not proportional to that of the power, and sooner or later comes to a maximum.

"The state of the *Atmosphere* is perhaps the most material of the four conditions, as we have it not in our power to alter it. The effects of moisture, damp air, and haziness, (which have been related in a paper where the causes that often prevent the proper

action of mirrors were discussed,) shew the reason why the apparent distance of a double star should be affected by a change in the atmosphere.

"The alteration in the diameter of *Arcturus*, extending from the first to the last of the ten images of that star, in the plate accompanying the above-mentioned paper*, shews a sufficient cause for an increase of the distance of two stars, by a contraction of their apparent disks. A skilful observer, however, will soon know what state of the air is most proper for estimations of this kind.

"I have occasionally seen the two stars of *Castor*, from one and a half, to two, and two and a half diameters asunder; but in a regular settled temperature and clear air, their distance was always the same. The other three causes which affect these estimations, are at our own disposal: an instance of this will be seen in the following trial. I took ten different mirrors of seven feet focal length, each having an aperture of 6.3 inches, and being charged with an eye-glass which gave the telescope a magnifying power of 460. With these mirrors, one after another, the same evening, I viewed the two stars of our double star; and the result was, that with every one of them the stars were precisely at an equal distance from each other. These mirrors were all sufficiently good to shew minute double stars well

* See *Phil. Trans.* for 1803, p. 232, Plate cxi.

and such a trial will consequently furnish us with a proper criterion, by which we may ascertain the goodness of our telescope, and the clearness of the atmosphere required for these observations.

"To those who have not been long in the habit of observing double stars, it will be necessary to mention, that, when first seen, they will appear nearer together than after a certain time; nor is it so soon as might be expected, that we see them at their greatest distance. I have known it take up two or three months, before the eye was sufficiently acquainted with the object to judge with the requisite precision."

A Star will not appear, in any Telescope, with a sharply defined disk, like a Planet, however beautifully perfect the Instrument is, until the *Magnifying* Power is in a certain proportion to the *Illuminating* Power,—to produce such an appearance, you must either increase the Magnifying, or diminish the Illuminating, power of the Telescope, by contracting its aperture.—See Sir W. H.'s Observation on *Castor*, in the Chapter of *Double Stars*.

In a good Achromatic of 2 feet focus, and $1\frac{6}{10}$ths inch aperture, and power of 100, I have seen *Castor* well defined, like two tiny Jupiters; but in an equally perfect $3\frac{1}{2}$ feet, with an aperture of $2\frac{3}{4}$ths inches, it required a power of 180 to give that clean, circumscribed, and decided disk to it—but when

limited to the same aperture as the 2 feet, with the same power of 100, it shewed the Star neater than the 2 feet shewed it with that power.—See the comparison of a 5 feet and 3½, in page 289 of the Chapter on *Illuminating Power*.

As a general Rule, when you wish a STAR *to appear with a clean circumscribed disk*, like a PLANET, the pencil of Rays must not be more than the 80th of an inch in diameter—that is to say, the power given by setting down the aperture of the Object-glass in tenths of inches, and multiplying that sum by 8, or the Speculum of a Reflector by 5 or 6.

---

FROM DR. HERSCHEL'S EXPERIMENTS FOR ASCERTAINING THE REAL FROM THE SPURIOUS DIAMETERS OF CELESTIAL AND TERRESTRIAL OBJECTS.

[Phil. Trans. vol. xcv. p. 31.]

" (7.)—This shews, that when the aperture of the telescope is lessened, it will occasion an increase of the spurious diameters, and when increased will reduce them.

" (8.)—It also shews, that the increase and decrease of the spurious diameters, by an alteration of the aperture of the telescope, is not proportional to the diameters of the stars.

"(9.)—But that this alteration acts more upon small spurious diameters, and less upon large ones."—*Phil. Trans.*

"The best eye-lens will give the least spurious diameter.—(p. 43.)

"Oct. 12, 1782.—I tried a new plain speculum, made by a very good workman, and found that when I viewed *α* Geminorum with 460, the vacancy between the two stars was barely 1½ diameter; but the same telescope and power, with my own small speculum, made the distance 2 diameters, so that the figure of this mirror affects the spurious diameters of stars.—(p. 44.)

"21*st Exp.*—Measures of the comparative amount of the spurious diameters, produced by the inside and outside rays.

"I divided the aperture of the mirror into two parts, one from 0 to 4·4, and the other from 4·4 to 8·8 inches.

"When I measured the spurious diameter of a Globule, the inside rays made it 40; with all the mirror open it was 31; and with the outside rays it was 22.

"(14.)—From this we may conclude, that the diameters given by the inside rays, by all the mirror open, and by the outside rays, are in an arithmetical progression; and that the inside rays will give nearly double the diameter given by the outside.—p. 54.

"23*d Exp.*—I examined *α* Geminorum with 410,

and with the outside rays the stars were considerably unequal, and 1¼ of the largest asunder. With all the mirror open they were more unequal, and 1½ diameter of the largest. With the inside rays they were very unequal, and 1⅞ths of the largest asunder."—P. 55 of Dr. Herschel's Paper, of vol. xcv. of the *Phil. Trans.*, being "Experiments for ascertaining how far telescopes will enable us to determine very small angles, and to distinguish the real from the spurious diameters of celestial and terrestrial objects," &c. &c.

The following letter from WILLIAM WALKER, the Astronomer, to the Author, is an interesting communication respecting *Double Stars*.

"Manor House, Hayes, Middlesex,
17th August, 1803.

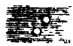
"DEAR SIR,

"I this morning received your proof of THE MOON, which is very like, and very prettily executed.

"Having, previously to the year 1791, had many proofs of the excellence of my achromatic telescope*, (which was made by Dollond, and is of 2¾ths inches aperture, and 44 inches focus,) I was determined, in that year, to ascertain whether it would not discover

* Which was purchased at Mr. Walker's Sale by Henry Browne, Esq. F.R.S.

to me the minutest objects in the heavens: and on Sept. 9, 1791, after having been exposed with the instrument near an hour in an open garden with the negative power of 180, I readily saw ε *Bootis* double.

"On the 11th Sept. ι Bootis, and η *Coronæ Borealis*, thus  

"25th Sept. I saw them again decisively as above, and shewed them to two or three friends, who were in the habit of using telescopes to celestial purposes: and who readily, without any indication from myself, pointed out on which side the small stars were situated in these two most delicate and difficult objects.

"26th Sept., three satellites of *Saturn*—the shadow of the ring on the planet—and a Belt—*d Serpentis*, δ *Herculis*—the *Pole* star—ι Bootis, and *h Draconis*, thus  powers 423, single eye-glass, and 180 and 133 negative powers.

"ε *Lyræ* is too distinctly double-double to be worthy of notice.

"Sept. 30th, 2 in the morning, *Rigel* thus  power 133. The star in *Monoceros* right fore foot treble, thus  powers 133, 180, and 423.

"I think your idea a very good one of shewing the comparative appearances, positions, and distances, of the small Double Stars, by the power of 180, in a 44 inch Telescope; and it might be added, that

this was merely for ascertainment of their relative distances: so that if it was mentioned afterwards with what power each Star was best seen, any person anxious on the subject might repeat the experiment.

"I fear you will find no *Micrometer* capable of measuring the distances of these most faint objects.

"I beg my compliments to Mrs. K. and my young friend; and remain, dear Sir,

"Yours very truly,

"W. WALKER."

To see the separation between the two Stars of η *Coronæ*, now, requires not only a very perfect but a very large Telescope, and most favourable circumstances.

Many a Star-gazer has bravely turned out on a bitter cold night, and stared at η *Coronæ*, till every particle of his patience and caloric have been fairly frozen out, (and his Eyes have cried for mercy,) without catching a glimpse of this delicate object.

In July 1825, I tried to see η *Coronæ* with an Achromatic of 2¾ths inches aperture, made by Mr. TULLEY for Mr. THOMAS TOMKISON, which I thought as perfect a Telescope as I ever saw, but it would not shew this Star double, neither has any Achromatic ever shewn it to me double.

I have heard of several Astronomical Amateurs being sufficiently unhappy because they cannot see this Star, and have doubted whether it was ever

visible; thinking the reason they could not see it was, (as Puff says in the Critic) because it was not in sight.

Mr. PETER DOLLOND, who had as good and as well-educated an Eye as perhaps ever Man had, told me, that about 35 years ago, he saw this star distinctly double, in Sir WILLIAM HERSCHEL's 7 feet Newtonian Reflector.

If the Stars have approached each other during the last 35 years, in the same degree that the two stars of *Castor* have separated from each other, it is no wonder they are not now very easily definable, and have become almost inseparable.

I read the above to the late Mr. PETER DOLLOND, on the 14th February, 1818, who replied, "Yes, that is all true enough; I saw it in Dr. Herschel's 7 feet Newtonian, which had an Aperture of $6\frac{3}{10}$ths inches, on the Terrace at the Royal Observatory at Greenwich." Mr. D. expressed himself much pleased with what I read to him. He appeared very cheerful, said that "his Health was good, only that his Sight was almost quite worn out in the service of Optics—and that he was then within a fortnight of completing his 87th year."

See Mr. HERSCHEL and Mr. SOUTH's Observations of this Star, in page 376, and Mr. TULLEY's Letter, in page 296—Mr. MOSELY's, in page 145—and Sir WM. HERSCHEL's particular directions for Observing it, in page 397 of this Book.

For defining DOUBLE STARS, *Reflecting Telescopes*, when made with due care for that especial purpose, have a decided advantage over *Refracting Telescopes*, even if the Illuminating and Magnifying Power of the two Instruments are equal — in as much as the *Reflectors give a Smaller Image of a Star*.—See the last paragraph of page 297—and Sir Wm. H.'s *Obs.* in page 384.

That Reflecting Telescopes are uncertain in their action—extremely apt to get *Out of Adjustment*—and are soon tarnished and spoilt, are very *Vulgar Errors*—*i. e.* unless they are in a *Wooden* Tube—if the Speculums are properly fitted in *Brass Tubes*, and are kept as carefully from damp air as a Refractor requires to be, they are as uniform in their action as Achromatics are.

I have had Gregorian Telescopes made by Mr. Watson and Messrs. Tulley, in use for 20 years, and they are in quite as perfect condition and adjustment now, as they were when first finished.—*All the attention that Reflectors require*, is to be exposed to the air for 15 or 20 minutes *before* they are used—and to be carefully covered up *afterwards*.

Many of the Telescopes which I have heard called *Out of Adjustment*—I know were never in—but originally bad Instruments which no Adjustment could improve.—See *Note* at the foot of page 343.

The change of the relative Magnitude of the Small Stars which accompany *Rigel*—the *Pole Star*, &c.

as seen with a Telescope of greater or less Magnitude, arises from the fainter points of Light becoming more visible, in proportion as they are more Illuminated by a larger Telescope—while the diameter of the Larger Star, which had sufficient intrinsic brightness to be perfectly visible with an aperture of 3 inches, continues the same with an aperture of 4 inches, or any larger aperture.

With an equal Magnifying power, the small Stars near *Rigel*, and the *Pole Star*, appear considerably larger in my 5 feet Achromatic, with an Aperture of $3\frac{8}{10}$ths Inches, than they do with my $3\frac{1}{2}$ feet, with an Aperture of $2\frac{7}{10}$ths Inches—what appeared in the $3\frac{1}{2}$ feet as a mere point of Light, and was only visible at intervals — in the 5 feet was constantly and easily seen — (see *Obs.* on *Rigel*) — but the Large Stars appeared of the same size. This Observation is a very happy illustration of the effect of *Illuminating Power*.

*The Colour of Blue Stars* appears stronger as the Telescope is larger, and is strongest in Reflecting Telescopes.—See pp. 277 and 458.

The reader may depend upon the truth of these assertions : it is not only the opinion of the "*Cook's Oracle*," but was confirmed to me by an Optician, who made some of the best Telescopes in the world, after he had had more than half a Century's experience.

Sir Wm. Herschel, in his *Obs.* of ε *Bootis*, in the

*Phil. Trans.* vol. xcv. p. 42, relates, that he saw it "half a diameter of the small Star, distinctly separate from the larger Star, with his 7 feet Newtonian, when the Aperture was limited to only 3½ inches, power 460."—See my *Obs.* of this Double Star, with a Gregorian of 4 inches Aperture, in pp. 297 and 458 of this Book.

" The *Newtonian Reflectors,* on the plan of my 7 feet one, as I have found, will give a much smaller image of the Stars than the 46 Inch Refractors.—Two Stars, which, in Refractors, as it were, run into each other, will in the Reflector remain separate."—Sir W. H. in *Phil. Trans.* vol. lxxv.

Not *One* Instrument in *Twenty,* of any construction, can be made to give a neat Image of a Star with its whole Aperture,—and not *Two* of Them will give quite so sharply defined an Image with the Whole Aperture as when it is to a certain degree contracted.

I do not think that any Achromatic of 2¾ths inches Aperture, and 3½ feet focus, can be made to shew Small Stars similar to that which accompanies *Rigel* so plainly,—or to give quite so neat an image of a large Star with the whole of that Aperture, as a fine 5 feet of 3¾ths Aperture will when it is limited to 2¾ths—I have never seen one that approximated within some degrees of it.

The more perfect vision in the 5 feet, is partly to be attributed to the greater original power of its

longer Object-Glass, and to its longer Eye-Glasses—(see page 289)—but what I have asserted is true of Telescopes of equal length; though the improvement from contracting the aperture is not in so high a ratio.

"If the Aperture of a Telescope be 5 or 6 inches, there will be required a piece of Metal 7 or 8 inches broad at least, because the figure will scarcely be true to the edges."—See Sir ISAAC NEWTON's *Letter to the Secretary of the Phil. Trans.*, March 26, 1672, vol. vii. p. 4032.

It may be supposed that Speculums are now worked with more accuracy than when "the Optician's Oracle," Sir I. Newton, wrote the above; however, I have not yet seen a Reflecting Telescope of 7 Inches Aperture, which did not define Stars better when it was contracted in a certain degree: but this I attribute as much to want of liberality in the Purchasers, and to want of industry in the Makers, as to any ungetoverable obstacle in the working of the metals.

I had in my possession for Two Years Mr. AUBERT's favourite Achromatic, of $3\frac{6}{10}$ths Aperture, which was a brilliant Day-Telescope, and with it I saw Planets very well—but could not see *Rigel* distinctly, until its Object-Glass was limited to $2\frac{3}{4}$ths inches—with $3\frac{6}{10}$ths the small Star accompanying *Rigel* was enveloped in the false light from the large one;—with $3\frac{3}{10}$ths inches it was not much better—but

with 2¾ths inches, the little Star was distinctly and easily visible, and it exhibited ε *Bootis*—γ *Leonis*, &c. as well as I have seen them in any Telescope of 2¾ths inches Aperture.—See Sir W. H.'s *Introductory Remarks to his Second Cat. of Double Stars*—and page 383 of this Book.

If your Telescope does not define Stars so well as you wish—make a pasteboard cover for the Object-end, with an Aperture of $\frac{1}{10}$th of an Inch less than that of the Telescope—and if that be too large, contract it by 10ths till the Image of a Star is neatly defined.

Very few persons, however, require Telescopes for this purpose. Objects which are so severe a test of a Telescope are as severe a trial to the Sight—and those who have due regard for their Eyes, forbear from straining them by all needless exertions: and the greatest exertion of the Eye I know of, is that of trying to see difficult Double Stars with Telescopes so small, that they have not enough Illuminating power to render the vision easy.

Of all the inventions for injuring our Eyes that fashion and folly have ever invented, none impairs them so rapidly and so irreparably as staring at Stars which are difficult to see, with *Tiny Telescopes* that it is difficult and generally impossible to see them with.—See pp. 3, 40, and 216.

When I was 45 years old, I was indiscreet enough to employ some hours during several Nights,

in looking so intently through Reflecting and Achromatic Telescopes, endeavouring to ascertain the comparative Illuminating powers of various Instruments, and the effect of variously constructed Magnifiers*, for shewing *the Division in the Ring of Saturn*, and for separating some of the faintest and closest *Double Stars*, that my Eye became extremely tired, and the sharpness of my Sight was sensibly impaired,—for two or three days after, I hardly knew any face that was 20 feet from me, and became so much alarmed about my Eye, (I have only One,) that I mentioned it to an eminent Optician, who did not then live quite a Thousand Miles from St. Paul's, who said, " Don't be uneasy; the same thing has happened more than once to myself; your Eye has been over-worked, give it a few days' Rest, and I dare say it will soon come round again."—His prediction speedily proved true.

One of the tests to which I put my Eye, and my 5 feet Achromatic, which has a double Object-glass of $3\frac{8}{10}$ths aperture,—was, to ascertain with how Low and how High a power I could see the Small Star near the *Pole Star*.—See *Pole Star*, page 447.

*Over-exercise of the Eyes*, will occasion a temporary exhaustion of them, in like manner as over-

* Some of these Experiments are related in page 57, and the nine following pages, and the consequence of the repetition of such hard Eye-work, at page 3.

exercise of the Legs will disable a person from walking with his wonted energy till Rest restores vigour to him.

I have often heard people complain of their Eyes being out of temper for several days, after being exposed to the glare of the Lamps at a Theatre, &c.—from being fatigued by sitting up after their accustomed Hour,—or from other causes which distressed their Nervous System, and put their Organs of Digestion out of tune, when Nervous Dimness of the Sight is as common as Nervous Deafness.

*The effective state of the Eyes*, like that of every other sense and fibre of our frame, depends upon hat of the Circulation,—which depends upon the vigour of our Heart, and that upon the strength of the Stomach, and the more or less stimulating Quality, and the Quantity of the material that it is supplied with.

I have mentioned my own case of *Dimness of Sight* in the preceding page, because I believe many Persons, from the want of such a hint, have greatly injured their Eyes, by having been induced, by similar Symptoms, to put on Spectacles sooner than Nature wished that they should,—in such cases, REST IS THE BEST REMEDY.

N.B. This subject is more fully explained in the *First Part of* "THE ECONOMY OF THE EYES."

## $\gamma$ ANDROMEDÆ.

I have several times seen this pretty Double Star, with a 1 foot Achromatic, of $1\frac{1}{10}$th of an inch Aperture, and a Magnifying power of 35. In these little Telescopes, the Smaller Star, which, with a Larger Instrument, and a larger power, appears of a *Blue* colour—appeared of the same Colour as the Larger Star, which it does in the largest Telescope until it magnifies about 60.

The greater the *Illuminating*, and, up to a certain degree, the *Magnifying* power of a Telescope, the more vivid appears the *Blue* colour of the Smaller Star, as I have remarked of $\varepsilon$ *Bootis*:—*The Blue Colour* of the Stars accompanying this Star and $\varepsilon$ Bootis, becomes vivid in proportion to their proximity to the Meridian, and the Magnitude and the Perfection of our Telescopes.

It is easily visible in a 30 Inch Achromatic, of 2 inches Aperture, with 80—best with 150; and in a Gregorian Reflector of three Inches aperture.

In a 5 feet Achromatic, of $3\frac{8}{10}$ths Aperture, is best with 250:—in this Telescope, with 44, it was plainly separate, but the Smaller Star appeared *white*—with 60, a *very pale Blue*—its Colour became deeper with 100—and with 250 it was Deepest, and the Two Stars best defined.

### SIR WM. HERSCHEL ON γ ANDROMEDÆ.

*Third Class of Double Stars.*

"5. * γ Andromedæ, Fl. 57. Suprà pedem sinistrum.

"Aug. 25.—Double. Very unequal. L reddish w; S fine light sky-blue, inclining to green. Distance 9″.254 a mean of 2 years' observations. Position 19° 37′ n. following. A most beautiful object.

"This double Star is one of the most beautiful Objects in the Heavens. The striking difference in the colour of the two Stars, suggests the idea of a Sun and its Planet, to which the contrast of their unequal size contributes not a little."—See Dr. H. in *Phil. Trans.* for 1804, vol. xciv. p. 364.

### α GEMINORUM

requires very little *Illuminating* Power: I have shewn it to several persons who did not know that it was a Double star, with the 1 foot portable Telescope, in sliding tubes, with an Object-glass of the usual aperture of $1\frac{1}{10}$th inch in diameter, to which I applied a *Pancratic* Eye-tube, which gave a power of 80 times, and they described to me its appearance very accurately.

On the 25th of March, 1819, *Mr. Pierce,* the Optician, with a Pancratic Eye-tube, which made a 1 foot Achromatic magnify 80 times, perceived *α Geminorum* to be double.

On the 5th of April, 1819, I shewed this with a power of 80 to *Mr. Wm. Brockedon,* the Painter, and to *Mr. Charles Turner,* the Mezzotinto Engraver in Ordinary to HIS MAJESTY.

*Castor* being so easily and distinctly visible in a small Telescope, provided the instrument be good, is an excellent test of defining power, and of the comparative effect of various Magnifying powers in various Telescopes, which, if they are excellent, should shew it as it is represented in Sir Wm. Herschel's diagram in the Frontispiece to this book.— See *Obs.* on SEEING *Double Stars,* at page 415.

1824, May 10th. Dumpy Gregorian, by Cuthbert, 2 inches aperture, and 4 inches focus, *Castor* very distinctly double, with 80 and 130.

On the 20th May, 1824, I saw the two Stars of *α Geminorum* in an Achromatic Telescope, with a Double Object-glass of 28 inches focus, and 2¾ths inches aperture — with a Single Double Convex Lens of $\frac{1}{10}$th of an inch focus, which produced a Magnifying Power of 280—as distinctly defined as Two Shillings on a bit of Black Cloth, and they appeared to be about the distance from each other represented in the Diagram.—See Sir WM. HERSCHEL'S *Diagram of Castor,* as it appeared in

his 7 feet Newtonian with 460, in the *Phil. Trans.* for 1782, and in the Frontispiece to this Book.

This Double Star is best in my 46 Inch, and 5 feet Achromatic, with 350.

1824, May 9th. Watson's* Gregorian, 4 Inches Aperture, and 11 Inches focus—with 260, *Castor* appears more separate, and the Diameters of the Stars appear less than with an excellent 3½ feet Achromatic, of 2¾ths inches Aperture.—See p. 297.

See *Obs. on Castor,* in Mr. HERSCHEL and Mr. SOUTH's Paper on *Double Stars,* in the *Phil. Trans.* for 1825, p. 103.

### SIR WILLIAM HERSCHEL ON CASTOR.

" *Second Class of Double Stars.*

" 1. † α Geminorum, Fl. 66. In capite præcedentis II[i].

" April 8, 1778.—Double. A little unequal. Both w. The vacancy between the two stars, with a power of 146, is 1 diameter of S; with 222, a little more than 1 diameter of L; with 227, 1½ diameter of S; with 460, near 2 diameters of L (*see fig.* 6); with 754, 2 diameters of L; with 932, full 2 diameters of L; with 1536, very fine and distinct, 3 diameters of L; with 3168, the interval extremely large, and still pretty distinct. Distance by the micrometer 5″.156. Position 32° 47′ n. preceding.

* Mr. WATSON's address is No. 14, Buckingham Street, Strand.

These are all a mean of the last 2 years' observations, except the first with 146.

"From my earliest observations on the distance of the two stars, which make up the double star in the head of *Castor*, given in the first of my catalogues of Double Stars, we find, that about twenty-three years and a half ago, they were nearly two diameters of the large star asunder.

"These observations have been regularly continued, from the year 1778 to the present time, and no alteration in the distance has been perceived: the stars are now still nearly two diameters of the large one asunder."—See page 420.

"By an Observation of the 10th of May, 1781, we have the diameter of the *largest* of the two stars to that of the *smallest*, as 6 to 5."—See Dr. HERSCHEL'S Paper in *Phil. Trans.* for 1803, vol. xciii. pp. 345, 6, and 7.

## ε LYRÆ.

ε Lyræ is easily seen double, with an Achromatic Opera-glass, with an Aperture of 1½ inch, which magnifies 5 times—*with which it appears like Castor, in my 5 feet Achromatic, when it magnifies* 450.

## SIR WILLIAM HERSCHEL ON ε LYRÆ.

"5 et 6.* ε Lyræ, Fl. 4 and 5.

"Aug. 29.—A very curious double-double star. At first sight it appears double at some considerable distance, and by attending a little, we see that each of the stars is a very delicate double star. The first set consists of stars that are considerably unequal. The stars of the 2d set are equal, or the preceding of them rather larger than the following. The colour of the stars in the first set, L very w; S a little inclining to r. In the 2d set both w. The interval between the stars of the unequal set, with a power of 227, is full 1 diameter of L; with 460, near 1½ diameter of L; with 932, full 1⅔ diameter; with 2010, 2⅓d diameters. The interval between the equal set, with a power of 227, is almost 1½ diameter of either; with 460, full 1¾ths diameter; with 932, 2 diameters; with 2010, 2½ diameters. These estimations are a mean of 2 years' observations. Position of the unequal set 56° 0′ n. following. Position of the equal set 72° 57′ s. following.

"ε *Lyræ*. II, 5 and 6.

"This remarkable double-double star has undergone a change of situation in each double star separately, which is not very considerable, but deserves

our notice, on account of a certain similarity in the directions of the alteration. The position of II, 5, Nov. 2, 1779, was 56° 5′ north-following; and, by a mean of three observations, taken Sept. 20, 1802, May 26 and 29, 1804, it was 59° 14′; which gives a change of 3° 9′; the motion of the angle being retrograde. The position of II, 6, on the same days, was 83° 28′, and 75° 35′, south-following. This gives a difference of 7° 53′; the motion being also retrograde." — Dr. H. in *Phil. Trans.* vol. xciv. p. 374.

---

## α HERCULIS.

June 12th, 1824.—30 Inch Achromatic, 2 Inches Aperture, with 72, the small Star just discernible; with 95, more easily seen; with 130, more separate; with a 30 Inch, with 2¾ths Aperture, the Blue Star much better seen.

### SIR WILLIAM HERSCHEL ON α HERCULIS.

"2. † α Herculis, Fl. 64. In capite.

"Aug. 29, 1779.—A beautiful double star. Very unequal. L r; S blue inclining to green; the colours with every power the same. The interval with 222, 1¾ths diameter of L; with 227, above 2 diameters

of L; with 932, above 3 diameters of L. Distance 4″.966. All a mean of 2 years' observations. A single measure with my last new micrometer, from centre to centre, 4″ 34‴. Position 30° 35′ s. following."

In Sir Wm. Herschel's introductory Remarks to his First Catalogue of Double Stars, in vol. lxxii. of the *Phil. Trans.* he says, "The little Star which is near *α Herculis*, by some, to whom I have shewed it, has been called *Green*, and by others *Blue*."

"*α Herculis*. II, 2*.

"The two stars of this double star have undergone a considerable change in their angle of position. By a measure taken May 20, 1781, it was 21° 28′ south-following†. April 3, 1783, two measures gave 25° 29. A mean of two measures, taken Feb. 21 and March 4, 1802, was 31° 38′. By five measures, taken in 1803, and the beginning of 1804, it was 31° 54′; and June 3, 1804, by a very accurate

* "The numbers after the name of the star, refer to my (Sir Wm. H.'s) Catalogues of double Stars, published in the *Philosophical Transactions*. For instance, II, 2, denotes that *α* Herculis is the 2d star in the 2d class."

† "By mistake, the first angle of position in my Catalogue is given 30° 35′, instead of 21° 28′, and should be corrected.—See *Phil. Trans*. vol. lxxii. Part I. p. 122."

measure, with an improved illumination of the wires, it was 32° 50′. This gives a change of 11° 22′, in 23 years and 14 days.

" It does not appear that the distance has undergone any perceptible alteration."—*Phil. Trans.* p. 360.

---

## γ LEONIS.

March 4th, 1825.—½ past 9—very fine night—5 feet Achromatic, with the whole Aperture 3$\frac{8}{10}$ths inches. The Two Stars of γ *Leonis* are as separate and as well defined with a power of 460, as those of *Castor* were with 150.

When the Aperture of this Telescope was contracted to 2$\frac{7}{10}$ths—the two Stars of γ *Leonis* were perfectly separated, and defined very distinctly with 190:—the Smaller Star is not so white as the Larger one.

See *Obs.* on γ *Leonis* in page 136 of Mr. HERSCHEL and Mr. SOUTH's Paper on *Double Stars*, in *Phil. Trans.* for 1825.

### SIR WM. HERSCHEL ON γ LEONIS.

" 28. γ Leonis. Fl. 41. In collo Lucida.

" Feb. 11, 1782.—A beautiful double star. Pretty unequal. L w; S w inclining a little to pale red.

With 227 and 228, distinctly separated; with 460, $\frac{1}{6}$th diameter of S; with 625, $\frac{1}{4}$th diameter; with 932, full $\frac{1}{4}$th diameter, or, when best, $\frac{1}{2}$ diameter of S; with 1504, $\frac{1}{4}$th diameter, well defined, and the difference of colours still visible; with 2176, not quite a diameter of S, pretty well defined, but exceedingly tremulous; with 2589, less than 1 diameter; with 3168, still pretty distinct, and about $\frac{3}{4}$ths diameter of S; with 4294, more than a diameter of S, but attended with the utmost difficulty of managing the motions; with 5489, the interval still somewhat larger, and if the object could be kept in the centre of the field, the eye might adapt itself to the focus, and get the better of the violent aberration; but the edges of the glass being of a different focus, the eye is constantly disappointed in its endeavours to define the object; with 6652, I had but a single glimpse of the star quite disfigured; however, I ascribe it chiefly to the foulness of the glass, which, on account of its smallness, is extremely difficult to be cleaned; with a 10 feet Reflector, 9 inches aperture, power 626, above $\frac{1}{2}$ diameter of S very distinct; with a 20 feet Reflector, power 350*, I see it very well. Position 5° 24′ n. following. A third star preceding. Dist. 1′ 51″ 23‴, pretty accurate for so great a distance. Position 31° 0′ n. preceding. A fourth star preceding the third, and

* "Too bright an object to be quite distinct."

somewhat smaller."—See *Phil. Trans.* vol. lxxv. p. 48.

"The distance of the stars $\gamma$ and $x$, as I shall again call the small one, has undergone a visible alteration in the last twenty-one years. The result of a great number of observations on the vacancy between the two stars, made with the magnifying powers of 278, 460, 657, 840, 932, 1504, 2010, 2589, 3168, 4294, 5489, and 6652, is, that with the standard power (460), and aperture ($6\frac{3}{10}$ths Inches) of the 7 feet telescope, the interval in 1782 was $\frac{1}{4}$th of a diameter of the small star, and is now $\frac{3}{4}$ths. With the same telescope, and a power of 2010, it was formerly $\frac{1}{2}$ of a diameter of the small star, and is now full 1 diameter. In the years 1795, 1796, and 1798, the interval was found to have gradually increased; and all observations conspire to prove, that the stars are now $\frac{1}{2}$ a diameter of the small one farther asunder than they were formerly. The proportion of the diameter of $\gamma$ to that of $x$, I have, by many observations, estimated as 5 to 4.

"The first-mentioned angle in 1782, is 7° 37′ north-following; and the last, which has been lately taken, is 6° 21′ south-following. The sum of these angles gives 13° 58′, for the change that has taken place in twenty-one years and thirty-eight days. To account for this, we are to have recourse, as before, to the various motions of the three bodies."—See *Phil. Trans.* for 1803, vol. xciii. p. 366.

## POLE STAR.

The Star called the *Pole Star*, is not actually upon the Pole—the Star that is, is a very small one—much smaller than the small Star which accompanies what is usually called the Pole Star, and is only visible in a very large Telescope.

Mr. H. Browne, F.R.S. informed me, that he has seen this Small Star in his Reflecting Telescope of 15 Inches Aperture.

I have seen the small Star, which accompanies *the Pole Star*, with a 2½ feet Achromatic, with *a treble* Object-glass of two inches and a quarter aperture, and power of 70, but have seen many Telescopes of 3½ focus that would not shew it.

The *Smaller the Magnifying Power* which will shew the Small Star as a detached point of Light, the better is the Telescope—this Observation applies to all Double Stars.

There is a peculiarity about the Small Star, near the Polar Star, if you can see it with a Low Power, it continues visible with any Higher power,—thus, I have seen it in a 5 feet Achromatic, with an Eye-glass of about Two Inches focus, and with one of only the 22d of an Inch focus.

I have seen Achromatics of 2¾ths aperture, which would not shew the Small Star with less than 80—in a lower power, it was enveloped in the light from

the Larger Star—but it was visible with any higher power.

I remember shewing it to some friends with my *Beauclerc* 46 Inch, which has a treble Object-glass of $3\frac{6}{10}$ths diameter, and Magnifying Power of 80; and when they expressed their surprise to see the small Star so plainly, wishing to shew it to them still more plainly, I pointed to it one of my Gregorian Reflectors of 7 Inches Aperture, and a power of 100, and was astonished to find that the Small Star was not near so plainly visible as in the Achromatic:—this Reflector shewed Planets and Objects in the Daytime beautifully, and from the much higher degree of its Illuminating Power, I thought that it would shew the Small Star in greater perfection than the Achromatic.

The reason it did not, I suppose was, that although Planets and Terrestrial Objects appeared sharp and well defined, yet that its Specula wanted that high degree of perfection which is indispensable for defining and bringing out faint points of Light.

1825, July 24. I see the Small Star in my Gregorian, which was made by WATSON, and is 11 inches focus, and 4 inches Aperture, with a power of 66 and 110.—See page 297 of this Book.

In my 5 *feet Achromatic,* which has a Double Object-glass of $3\frac{8}{10}$ths Aperture, the small Star, near *the Pole Star,* was a decidedly detached point of light with a single eye-glass, which gave the

Telescope a power of only 28, *i. e.* with the 2d E. G. of a compound Astronomical Eye-piece which magnifies = 44 times—and it was visible with 20 intermediate Eye-tubes, the highest of which magnifies 1386 times, and is a single Convex lens of the 22d of an inch focus.—The Object-glass being of

63 Inches focus
gave, multiplied by 22

126
126

*the Magnifying Power* 1386.

This Instrument is one of the *chef-d'œuvres* of the late Mr. PETER DOLLOND—who thus speaks of it to the Gentleman he sold it to, Mr. G. Hodgson, F.R.S., (and of whom I purchased it,) in his Letter, which is now before me, dated Nov. 11, 1803 :—"It has been made 10 years, and I can say that it is one of the best I ever made, and such as I cannot expect to be able to equal."

With my *Beauclerc Achromatic*, of 46 inches focus, and a treble Object-glass of $3\frac{6}{10}$ths inches in the clear aperture, I have seen that minute point of light near the Pole Star, with the following powers, measured by a *dynameter* invented and made by the late ingenious *Mr. Ramsden:* 40, 80, 150, 250, 350, 420, 700; and even with 1123 times the small Star was still visible. *Mr. William Walker,* the astro-

nomer, was observing with me, and also saw this. *Mr. Charles Fairbone*, mathematical instrument maker, of Great New Street, Fetter Lane, saw it again very distinctly on the 30th August, 1807. *Mr. Samuel Pierce*, Optician, observed the same on the 26th May, 1811.

*The Polar Star* is as proper as any, for a test of the light and distinctness of a Telescope;—it is easily found, and always above the horizon, and so it is the more desirable, as it is a more universally attainable test.

I mention the foregoing observations, merely as authenticated and curious facts how far magnifying power could be carried on this object, as it was with evident detriment to vision when higher than about 100, which shewed this star more pleasantly, and the illuminating and magnifying powers appeared to be in more perfect proportion, than with any of the higher or the lower powers.

1825, April 4th.—*Mr. Tulley's* 12 feet Achromatic, 7 inches Aperture:—the Small Star, which accompanies the Pole Star, with 100, as distinct and as steady as one of Jupiter's Satellites—with a single lens of 6 inches focus, which produced a power of 24, the small Star appeared as it does in an Achromatic of 3½ inches Aperture; with a power of 80, it was discernible, with a single lens of 8 inches focus, which gave a power of only 18.—See

in page 348 of this Book, an Observation of the *Double Ring*, and of the 6th and 7th *Satellites of Saturn*, with this 12 feet Achromatic.

This last Observation illustrates the effect of Illuminating Power: this faint star being as easily seen in the 12 feet Achromatic, with an aperture of 7 inches, with a power of only 24, as in the 5 feet, with an Aperture of $3\frac{8}{10}$ths inches, with a power of 44.

SIR WM. HERSCHEL ON THE POLE STAR.

" *Fourth Class of Double Stars.*

" 1. α Ursæ minoris, Fl. 1. Stella Polaris.

" Aug. 17, 1779.—Double. Extremely unequal. L w; S r. Distance 17″ 15‴. Position 66° 42′ s. preceding.

" *α Ursæ minoris.* IV, 1.

" There has been a small alteration in the relative situation of the pole star; but when we consider that this double star is of the fourth class, we cannot expect that any great change in the angle of position should have taken place in the course of 20 years. The position, Dec. 19, 1781, was 66° 42′ south-preceding; and June 17, 1782, it was 67° 23′. A mean of both measures, is 67° 3′. March 4, 1802, the position was 61° 43′; which gives a difference of 5° 20′, in 19 years and 350 days."—Dr. H. in *Phil. Trans.* vol. xciv. p. 382.

## RIGEL.

October 24th, 1807.—The HONB^le. STEWART M'KENZIE's Travelling Telescope of • 27 Inches focus, having *a treble Object-glass 2¼th inches in diameter*, made by Mr. RAMSDEN :—the small Star, near *Rigel,* seen very easily, and well separated from the large Star, with the usual compound Astronomical Eye-pieces, magnifying 70 and 110 times.

This Telescope was mounted in two tubes, one of which slided within the other : the Object-glass had been made many years, and when it performed in the extraordinary manner I have related, there was that sort of haze between its Glasses which Age and Damp Air often produce between Object-glasses without any apparent detriment to their vision—for I never saw an Achromatic of 2¼ths aperture, that was more brilliant as a Day Telescope, or that would shew *Rigel,* and many other Double Stars, so plainly as this. However, with the hope it would be still better if the Glasses were quite clean—I had the Object-glass taken to pieces to be wiped, and, alas! when re-adjusted, it had lost all that superlative defining power I have mentioned above.

This I mention as a caution to those who have a fine Object-glass in such a state—to be content, and not run the risk of spoiling it by having it taken asunder.—See Remarks on this *Vegetation,* in pages 336 and 337 of this Book.

This is the only Telescope of the Aperture which I have in thirty years met with, which would shew these Objects.

I have met with many Achromatics of 44 Inches focus, and 2⅗ths aperture, which would not shew them.

For the following observations I am indebted to Mr. Evanson, of the Stamp Office:—

"In consequence of your having manifested a desire to have an account of the powers by which I have been enabled, with a 30 inch Object-glass, to see some difficult double stars, I write this, in compliance with your request, to inform you, that with a power of 80 applied to a 30 inch Object-glass, having an aperture of 2 inches, I have very distinctly seen the small Star, near the Pole Star.

"With a 3 feet Object-glass, made by the ingenious Mr. Tulley, of Territ's Court, Islington, I have discerned $\gamma$ *Leonis* to be evidently double, with a power of 160, and $\varepsilon$ *Bootis* with a power of 160.

"The number of minutes and seconds comprehended in the field by any Eye-piece, is easily ascertained by observing the time of the transit of any star or planet over the field, from the instant of its coming to the meridian; then a very easy trigonometrical calculation, shewing the number of minutes and seconds which must be passed in that time, will manifestly denote the extent of the field of view. See page 182.

"Hence, likewise, may be deduced another mode

of ascertaining the magnifying powers of Telescopes with the greatest exactness."

1824, January 13th, 10 o'Clock. *Rigel.* With P. D.'s favourite 5 feet Achromatic, (see page 47,) while the aperture was contracted to 2$\frac{3}{4}$ths inches: with 44, I could not perceive the Small Star, which was seen very plainly, and perfectly separate from the larger Star, with 60, 100, and 200.

With the whole Aperture of 3$\frac{8}{10}$ths, it was best with 100 or 130; not so plain with 260; and with 450 it was not perceivable.

With a 44 Inch Achromatic, of 2$\frac{3}{4}$ths Aperture, it was best seen with the power of 80—and not visible with 180.

With the *Beauclerc* 46 Inch, best with 100.

The result of these Observations is, that *Rigel* to be seen well, must be very close to the Meridian, that it is a very severe test of defining power—more so than it is of Illuminating or of Magnifying Power, as it was distinctly visible with a power of 70, and a *treble* Object-glass of 2$\frac{1}{4}$th inches Aperture; and with a *double* Object-glass of 3$\frac{8}{10}$ths Inches Aperture, and 450, it was no more to be seen.

If the Telescope be not *extremely* perfect, the Small Star is enveloped in the false light from the very bright Large one—therefore, if the Image is not very neat, contract the aperture of your Telescope by 10ths of inches till it is, by this means you will sometimes see the Small Star very distinct from the Large one,

in Telescopes which, with the whole Aperture, will not shew it with any power.—See an account of the good effect produced by contracting the Aperture of Mr. AUBERT's 46 inch, at page 431 of this Book—and Sir Wm. H.'s account of this Telescope on γ *Leonis*, at page 383.

Dec. 1824.—In my *Herschel* 7 feet Newtonian, power 242, very distinctly, and well seen.

Jan. 17th, 1825.—In the same 7 feet, with 160, extremely well defined—*the Small Star* appeared, as Sir W. H. has described it, *inclining to Red**, the tint stronger than in the 5 feet Achromatic—but when the powers were equal, the Stars are more distinctly separated in the latter Telescope.

In Mr. HERSCHEL and Mr. SOUTH's *Obs.* on *Double Stars*, in the *Phil. Trans.* for 1825, p. 75, *Rigel* is described as " extremely unequal ; large White ; small *Bluish ;* 1st and 10th Magnitudes."

SIR WM. HERSCHEL ON RIGEL.

" 33. β Orionis, Fl. 19. In sinistro pede splendida.

" Oct. 1, 1781.—Double. Extremely unequal. L w S inclining to r. With 227, 2¼th or 2½ diameter of *Rigel ;* with 460, more than 3 diameters of L Distance 6″ 27‴. Position 68° 12′ s. preceding.

* See Sir Wm. H.'s *Obs.* thereon, with his 20 feet Reflector, in pp. 277 and 385.

The small star not wanting apparent magnitude, is better to be seen with my Power of 227 than with 460."

*Rigel* is more difficult to see well than the Pole Star is. — See Sir WM. HERSCHEL's *Remarks*, preceding his 2d Cat. of Double Stars, in page 385.

See an *Obs.* on the *pale Red Colour* of the Small Star, which accompanies *Rigel*, in Sir Wm. H.'s paper, in vol. lxxv. of the *Phil. Trans.*—and in pages 277 and 385 of this Book.

" *Rigel.* II, 33.

" This bright star has undergone a change of situation with regard to its distance from the small one, which is near it; but, in the angle of position, very little difference can be perceived. By eleven measures, taken between Jan. 1, 1802, and Feb. 18, 1803, the mean position is 69° 5′ south-preceding; which is but little more than 68° 12′, the measure of Oct. 1, 1781, given in my Catalogue.

" The distance was estimated, Oct. 1, 1781, with 460, to be more than 3 diameters of Rigel; and, as I supposed it to be one of those double stars, of which I might ascertain the vacancy between the two stars, by estimating the number of diameters of the large one that would fill it up, I placed the star in the second class. However, by a measure taken

with a micrometer, Oct. 22, 1781, the stars were found to be far enough asunder to come into the third class. By a mean of six measures, which were taken the first 18 months of my observing the star, their distance was 9″ 32‴; and, by a repetition of estimations, it appeared, Dec. 22, 1781, that the vacancy between the two stars was not less than 4 diameters, and, when the air was tremulous, 4 or 5. After an interval of more than 21 years, having omitted estimations by the diameter, as not very proper to be used with these stars, I wished to compare their distance with the former estimations; and, with the same instrument, and same magnifying power that had been used before, the vacancy, Feb. 22, 1803, amounted to 5 or 6 diameters of the large star; so that, certainly, an increase of distance must be admitted."—Dr. H. in *Phil. Trans.* vol. xciv. p. 380.

## ε BOOTIS.

ε *Bootis*, was observed on the 25th of May, 1819, by Mr. H. Browne, F.R.S. and myself, with an Achromatic Telescope of $2\frac{7}{10}$ths aperture, made by Mr. George Dollond. With a Pancratic Eye-tube, magnifying 270, the two Stars were

distinctly defined, without either rings or rays, &c. around them. This was in an extremely fine clear evening, the air quite still, and the star very near the meridian. The *Blue* colour of the smaller star was remarkably bright for so small an aperture—but this 30 Inch Achromatic Telescope would not exhibit a glimpse of the small Star which accompanies *Rigel*, nor of the small Star near *the Pole Star*. It was a remarkably brilliant Day-Telescope, but as its Object-glass was over-corrected, it did not shew Planets of a good colour. I mention these particulars, because I have met with those who have thought that if a Telescope would not shew the two Stars of ε *Bootis* distinctly, that it could not be good on any object, and that if it would, it would be excellent on All.

As this Double Star is so frequently referred to as a Test of Telescopes, I have written at large upon it.

I have seen $3\frac{1}{2}$ Telescopes of $2\frac{3}{4}$ths inches Aperture, which would shew the *Pole Star*, but failed entirely at *Rigel* and ε *Bootis*.—See page 284.

I have never seen* but one Telescope of $2\frac{7}{10}$ths Aperture, that would distinctly divorce the *Blue* Star, which in the finest Achromatics that I have seen of such small Aperture, was enveloped in the

* See what I mean by SEEING in line 15 of page 415.

ring of false light which surrounds the Larger Star,—the utmost I have ever seen with them, was a little tiny white wen on the left side of the large Star.—I cannot account for the extreme partiality which Opticians seem to have for the power of 180 with this Telescope—it is too much for a Planet, it is too little for a Double Star, for which 200 or 220 would be much more effective.—See line 6th of page 422.

These Stars can seldom be satisfactorily separated with less than a power of 250, and with that, an Object-glass of 2¾ths Aperture has not light enough, unless it be of 5 feet focus. I see it with my 5 feet when limited to 2¾ths Aperture; but the Blue Star requires a great deal of good light to shew it well, and is much better seen and defined with the whole Aperture of 3$\frac{8}{10}$ths inches, than it is when it is contracted, and is best seen with a Single Eye-glass.

This Double Star is seldom seen distinctly with an Achromatic with a less Aperture than 3¾th, or with a Gregorian Reflector of less than 5 inches.

On the 24th July, 1825, I saw it with my *Gregorian* of 4 inches Aperture and 11 inches focus—with 166, the small Star, *Blue*, very sharply defined, and distinctly separated from the Larger Star,—and also with 260.

On July the 27th, I shewed the above to *Mr*

*Philip Hardwick*, the Architect, who saw it perfectly—within ten minutes after, we looked at it with my 5 feet Achromatic; with 180, the small Star did not appear so *Blue* as in the Reflector.

On July 28th, *Mr. Seaman*, of Upper Gower Street, and *Mr. Tomkison*, of Russell Place, saw this—and on the 29th, *Mr. Cuthbert*, the Optician, and my Son, *Mr. W. B. Kitchiner*.

I have inserted the names of the Persons who observed this, because I have seen some Reflecting Telescopes of 4 inches Aperture which were not sufficiently perfect to perform what I have stated;—if it had been seen with only a single Eye on a single night, it might have been considered merely an optical delusion; and I have made it a rule, in all my works, never to present the Reader with merely my own simple assertion on any extraordinary point, when I could produce also collateral proofs which would be entirely convincing:—the Price charged by Mr. Watson for such a Gregorian is £33. 12s.—See p. 438.

1823, May 11th.—With the *Beauclerc** 46 Inch, and with a single convex lens magnifying 700, I saw these two stars beautifully distinct; and the space between them, I think, could not be less than 1½ diameter of the larger Star. *Mr. Hardy*, the Watchmaker, saw this.

* For an account of this fine Object-glass, see page 26 of this Book.

1811, May 26.—ε *Bootis,* with Beauclerc 46 inch, with 350 and 700. *Mr. Pierce,* the Optician, observed this with me, and signed his name in my Journal.

1825, July 28th.—With the *Beauclerc* 46 inch, the colour of the *Blue* Star was evident; and it was perfectly round, and detached from the larger Star with a power of 200. I never saw it so positively defined, and so perfectly separated, with so low a power with any other Telescope. The *Rev. T. Hussey* observed this with me.

April 21st, 1824.—With *P. Dollond's* 5 feet Achromatic, the Stars were separated with 180—the colour of the two stars nearly the same—the colour of the Blue Star visible with 250, stronger with 350, and stronger still with 450.

With this 5 feet, 350, the Blue Star, is seen as distinctly separated from the larger Star, as can be desired—and the field of view being larger, and the objects longer passing it than with 450, with which they flit by with very inconvenient rapidity, I have fixed 350 as the highest useful and agreeable power—360 was the highest compound Eye-piece to the 5 feet Telescope, which *Jesse Ramsden* made for *Sir George Shuckburgh,* for his Equatorial.—See vol. lxxxiii. of the *Phil. Trans.* pp 103 and 4, where he says, that "400 seems to be the maximum that this Glass will bear; with 500, the image is not so well defined; with 200 and 300, it is beautifully distinct and

bright."—See the Account of this Glass, at page 50 of this Book.

ε Bootis, in Dr. HERSCHEL and Mr. SOUTH'S *Obs.* on *Double Stars*—(see page 204 of the *Phil. Trans.* for 1825)—is thus described, "Large, Yellow; Small, Blue Green—a very marked Contrast of Colours."

### SIR WILLIAM HERSCHEL ON ε BOOTIS.

"This beautiful double Star, on account of the different colours of the Stars of which it is composed, has much the appearance of a *Planet* and its *Satellite,* both shining with innate but differently coloured light.

"There has been a very gradual change in the distance of the two stars; and the result of more than 120 observations, with different powers, is, that with the standard magnifier, 460, and the aperture of 6.3 inches, the vacancy between the two stars, in the year 1781, was 1½ diameter of the large star, and that it now is 1¾ths. By some earlier observations, the vacancy was found to be considerably less in 1779 and 1780; but the 7 feet mirror then in use was not so perfect as it should have been for the purpose of such delicate observations. By many estimations of the apparent size of the stars, I have fixed the proportion of the diameter of ε to that

of $\gamma$, as 3 to 2. August 31, 1780, the first angle of the position measured 32° 19′ north-preceding; and, March 16, 1803, I found it 44° 52′, also north-preceding: the motion, therefore, in twenty-two years and two hundred and seven days, is 12° 33′. It should also be noticed, that while the apparent motion of $\alpha$ *Geminorum* and of $\gamma$ *Leonis*, is retrograde, that of $\epsilon$ *Bootis* is direct."—See Dr. H.'s Paper in the *Phil. Trans.* for 1803, vol. xciii.

"August 20th, 1781.—I saw $\epsilon$ Bootis with 460, and the vacancy between the two Stars was 1¼th diameter of the large one. I then reduced the aperture of the Telescope by a circle of pasteboard from 6.3 inches to 3.5, and the vacancy between the Stars became only ½ diameter of the small Star.

"The proportion of the diameters of the two Stars to each other was also changed considerably; for the small one was now at least ⅔ds, if not ¾ths, of the large one."—*Phil. Trans.* vol. xcv. p. 42.

"The interval between very unequal Stars, estimated in diameters, generally gains more by an increase of magnifying power than the apparent distance of those which are nearer of a size. Instances of the former may be found in the first class, the 1st, 7, 29, 35, 37, 39, 53, 59, 63, 64, 72d Stars; of the latter, the 16th, 28, 33, 45, 46, 73, 81st Stars. However, this only seems to take place

when there is a difficulty of seeing the object well with a low power, which being removed by magnifying more, the distance is, as it were, laid open to the view."—Dr. H.'s *Note*, at foot of page 51 of vol. lxxv. of the *Phil. Trans.*

"With regard to small Stars, that become visible by an increase of Magnifying power, ($\alpha$ Lyræ, for instance,) we may surmise, that it is partly owing to the greater darkness of the field of view, arising from the increased power, and partly to the real effect of the power; for, though the real diameter of a Star, notwithstanding it be magnified a thousand times, should still remain smaller than the minimum visible, yet since a Star of the seventh magnitude may be seen by the naked eye, we may conclude, that the light of a Star subtends incomparably a larger angle than its luminous body; and this may be in such a proportion, with very small Stars, that the power of the Telescope shall be just sufficient to magnify the real diameter so as to bring it within the limits of this proportion, whereby the Star will become visible."—Dr. H.'s *Note* at the foot of page 82 of the *Phil. Trans.* for 1785, being vol. lxxv.

" *First Catalogue of Double Stars.*

" FIRST CLASS.

" 1. $\epsilon$ Bootis. Flamst. 36. Ad dextrum femur in perizomate.

"Sept. 9, 1779. Double. Very unequal. L reddish; S blue, or rather a faint lilac. A very beautiful object. The vacancy, or black division between them, with 227, is ¾ths diameter of S; with 460, 1¼th diameter of L; with 932, near 2 diameters of L; with 1159, still further; with 2010, extremely distinct, 2¾ths diameters of L. These quantities are a mean of 2 years' observations. Position 31° 34′ n. preceding."

---

### α LYRÆ.

June 3, 1824.—The very faint and small Star which accompanies *α* Lyræ, is not perceivable with my 5 feet Achromatic, with the Huygenian Eye-piece, which magnifies 250—but is distinctly visible with 350, and is seen still more plainly with 460, with which it appears about twice the distance directly above *Lyra*, (with an inverting Eye-tube,) that the small Star, near the Polar Star, appears to be from the Pole Star with a power of 80.—I saw it most easily when the Large Star had left the field, and it was discernible when the Aperture was contracted to 2¾ths; but I tried to see it during the same 10 minutes with a very fine 3½ feet Achromatic, with an Aperture of 2¾ths inches—and could not discern it.—See Mr. Mosely's Observation of this Star, in page 146 of this Book.

The visibility of this Star appears to be of the same nature as the small Star of the quintuple Star ε *Lyræ*, which is hardly visible in an Achromatic of 2¾ths Aperture, with 70—but easily seen with 150, and is exactly the reverse of *Rigel*, which I saw best in the 5 feet Achromatic with 130—but which with 460 was no longer discernible.—See *Obs.* on *Rigel*—and Sir WM. HERSCHEL, in vol. lxxii. of the *Phil. Trans.*—and in pages 387 and 388 of this Volume.

May 6th, 1825, at 10 o'Clock.—The 5 feet Achromatic—the small Star not visible with less than 350—better with 460—also with a single convex lens of the 22d of an inch focus, which produced a power of 1386.

May 9th, 1825.—Saw the same with the 5 feet—tried a very fine 46 Achromatic, which has a treble Object-glass of 3⅞ths Aperture, and could not see the small Star with 350—this Telescope shewed the small Star, near the Polar Star, with that power very plainly.

### SIR WILLIAM HERSCHEL ON α LYRÆ.

"39. α Lyræ, Fl. 3. In testa fulgida.

"Sept. 24.—Double. Excessively unequal. By moonlight I could not see the small Star with 278, and saw it with great difficulty with 460; but in the absence of the moon I have seen it very well with

227. L fine brilliant w; S dusky. Distance 37″ 13‴. Position 26° 46′ s. following.

"Oct. 22.—Having often measured the diameters of many of the principal fixed Stars, and having always found that they measured less and less the more I magnified, I fixed on this fine Star for taking a measure with the highest power I have yet been able to apply, and on the largest scale of my new micrometer I could conveniently use. With a power of 6450, (determined by experiments on a known object at a known distance,) I looked at this Star for at least a quarter of an hour, that the eye might adapt itself to the object; having experimentally found, that the abberration by this means will appear less and less, and, in the Telescope I used on this occasion, with powers from 460 to 1500, will often quite vanish, and leave a very well-defined circular disk for the apparent diameter of the Stars. The diameter of *α Lyræ*, by this attention, appeared perfectly round, and occasionally separated from rays that were flashing about it. From the very brilliant appearance of the Star with this great power, and a pretty accurate rough calculation founded on its apparent brightness, when observed with the naked eye with 227, with 460, with 6450, I surmise, that it has light enough to bear being magnified at least a hundred thousand times with no more than 6 inches of aperture, provided we could have such a power, and other considerations would allow us to

apply it. When I had as good a view as I expected to have, I took its diameter with my new micrometer on a scale of 8 inches and 4428 ten thousandth to 1″ of a degree, and found it subtended an angle of 0″.3553. I had no person at the clock; but suppose the time of its passing through the field of my Telescope, which in this great power is purposely left undefined, and as large as possible, was less than 3 seconds."—See Sir Wm. H.'s four diagrams of *α Lyræ*, in page 400 of this Book.

---

## THE MAGNIFYING POWERS

Which I have mentioned in my own Observations, I carefully measured by a *Dynameter*, made by Mr. Jesse Ramsden, (see page 238,) and a *Pearl Dynameter*, made by Mr. George Dollond, excepting the *Deep Single Lenses*, and the Powers I have stated as produced by them, are those which were produced by multiplying the focal length (in inches) of the Object-glasses by the focal length of the Lenses, as stated to me by Mr. Dollond, who made them for me.

I request those who may repeat any of the Observations which I have recorded, to read Chapter XVI., and to *carefully ascertain themselves the*

*actual Magnifying powers of their Instruments,* or they must not be surprised if they give extremely different results from those which I have set down—a difference of 10 times will sometimes give quite a different vision.—See line 19 of page 165.

In the early part of my Telescopical pursuits, I was several times strangely deceived by mistatements of the Magnifying power of the Eye-pieces of the Instruments I purchased—sometimes I found a Day Eye-tube of only 40 called 55—of course I thought that a prodigiously brilliant Glass, which appeared as bright with 55 as other Telescopes of equal Aperture were with 40.

I met with Astronomical Eye-tubes, which were made to look like, and were called, 180, which did not magnify more than 125—and then I wondered that the Telescope would not shew those Double Stars which I had seen with 180.

A Pearl Dynameter may be purchased for about 12*s.*—the slip of Pearl is divided into 200ths of an inch.

*To measure the Magnifying power of a Telescope* is very easy with this simple instrument;—suppose the aperture of its Object-glass, or Object-metal, to be Three Inches—adjust it to distinct vision at a distant object—then adjust the Dynameter so that you can distinctly see the division marked on the Pearl—then hold it before the Eye-

piece of the Telescope, and adjust it till the pencil of Rays is distinctly and sharply defined; observe how many divisions it covers, reduce the diameter of the Object-glass into 200ths of inches — thus calling a 3 Inch O. G. 600, divide that by the number of divisions covered by the pencil in the Dynameter, which, if the Telescope magnifies 75, will be —

Diameter of Pencil Diameter of

) 600 ( 75 Magnifying Power.
56

40
40

FINIS.

*The Author had no sooner seen the little word* Finis, *at the end of the last proof sheet, than he began to think, and to fear, that notwithstanding all the care he has taken to deserve your praise, Gentle Reader, it is, nevertheless, hardly among the possibles, that all may be entirely pleased; and some may say, and with no faint voice, "There is not a page in this book that is worth a farthing."—To such he says, "Well,—You shall not pay a farthing for it—You shall have his* 470 *pages for* 9*s.—i. e. for*

*$\frac{1}{4441}$th part of what he has paid* for it!—Well—you may read it in three days—that is in $\frac{1}{3650}$th part of the time† that he has been writing it—Well—then the Author will venture to hope that the Reader will not think that either his Money or his Time have been ill spent; and that he will be so good, as to grant the request made by the Author in the Preface to the "First Part of the Economy of the Eyes."*

* £2,000. † 30 Years.

---

That this book has its faults, no one can doubt,
Although the Author could not find them out.
The faults you find, good Reader, please to mend,
Your comments to the Author kindly send:
He will repay you with the honour due—
Your name, with praise, shall be affixed unto
Whate'er you write, that he has any hope
May any way improve the Telescope.—
Well-meant advice, the Author ne'er will sneer at,
His maxim is, "PALMAM QUI MERUIT FERAT."

# INDEX.

## A.

## B.



## C.

D.

## E.

## H.

## N.

S.

## T.

THE END.

LONDON:—PRINTED BY J. MOYES, BOUVERIE STREET.

*The Whole of Dr. KITCHINER's WORKS, consisting of the following, may be had of all Booksellers in Town and Country.*

Dedicated, by Permission, to the King,

The LOYAL, NATIONAL, and SEA SONGS of ENGLAND, for One, Two, and Three Voices; Selected from original Manuscripts and early printed Copies, in the Library of WILLIAM KITCHINER, M.D. One Volume folio. Price 2l. 2s. Boards.

Among 110 other Compositions, *John Bull's* "God sabe the Kinge," *is now first printed* in this number; also, the earliest-printed copy of "GOD SAVE THE KING;" and for the *first time* is also now published *a Complete Score* thereof for a full Band, for Voices and Instruments.

The Songs are so arranged, that they may be sung as a SOLO,—a DUET,—or a TRIO.

## ON SINGING.

*In 12mo. Price 4s. Boards.*

OBSERVATIONS on VOCAL MUSIC and SINGING, and Rules for the Accent and Emphasis of Poetry, which will ensure the Proper Pronunciation and Effective Expression of the Words.

"The finest Compositions frequently fail of producing half the impression they are capable of making on the Mind, from being sung with an injudicious Emphasis, or a false Accent."—AUTHOR'S OBSERVATIONS.

The SEA SONGS of CHARLES DIBDIN; with a MEMOIR of his LIFE and WRITINGS. By WILLIAM KITCHINER, M.D. This Work comprises AN HUNDRED SEA SONGS, &c. Price *One Pound Twelve Shillings*, neatly Half-bound.